

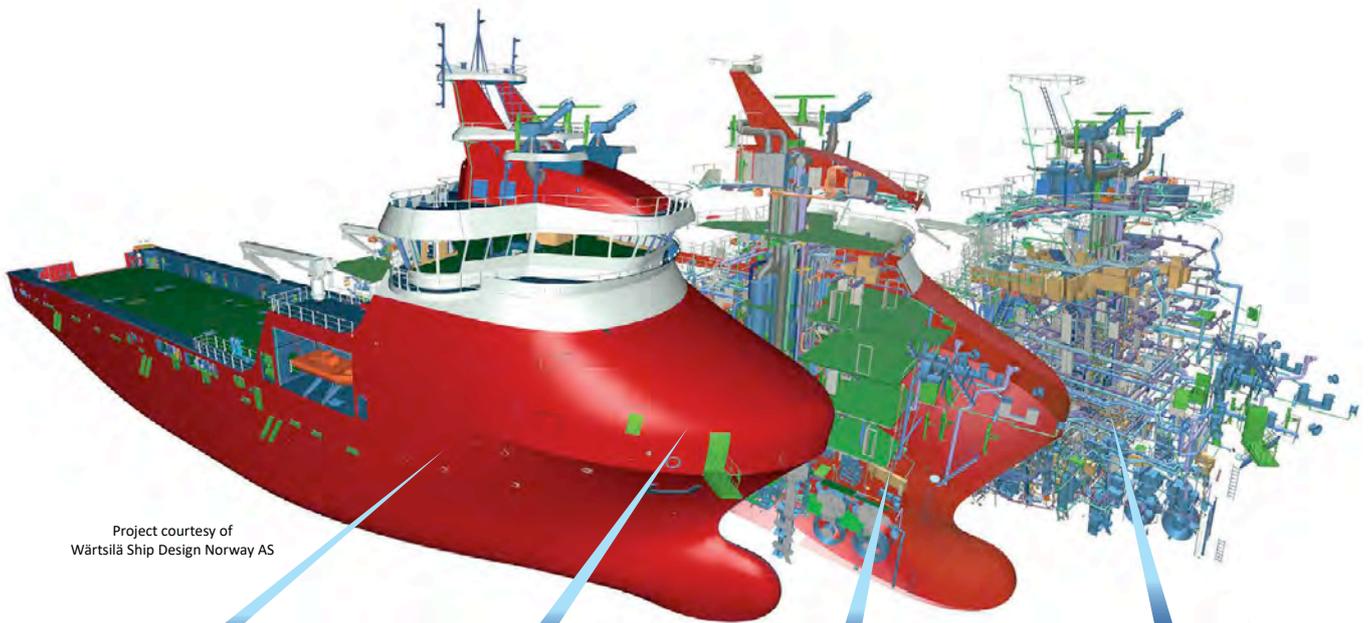


# THE NAVAL ARCHITECT

International journal of the Royal Institution of Naval Architects | [www.rina.org.uk/tna](http://www.rina.org.uk/tna)

Cruise ships / Accommodation & interiors / Propellers & thrusters / China / CFD & hydrodynamics / **February 2018**

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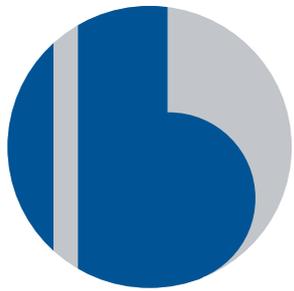


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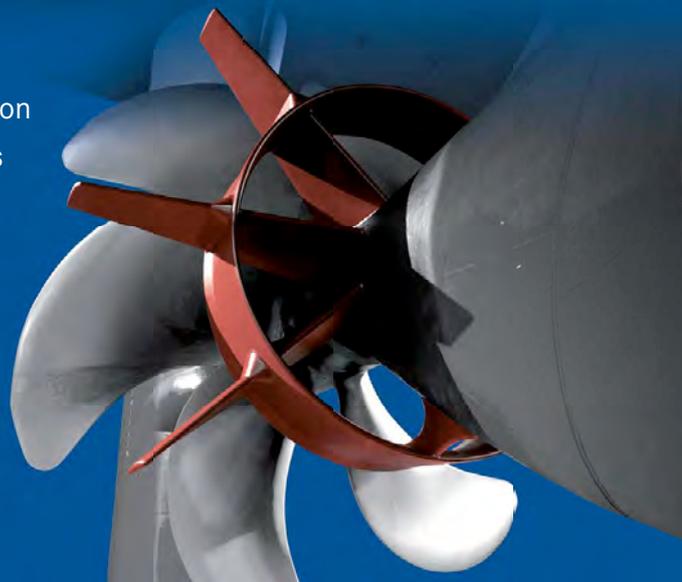
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**Advertisement Production Manager:** Stephen Bell  
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**Publisher:** Mark J Staunton-Lambert

**Advertising Sales:** J P Media Services  
 Email advertising: jpayten@jpm mediaservices.com  
 cseldon@jpm mediaservices.com  
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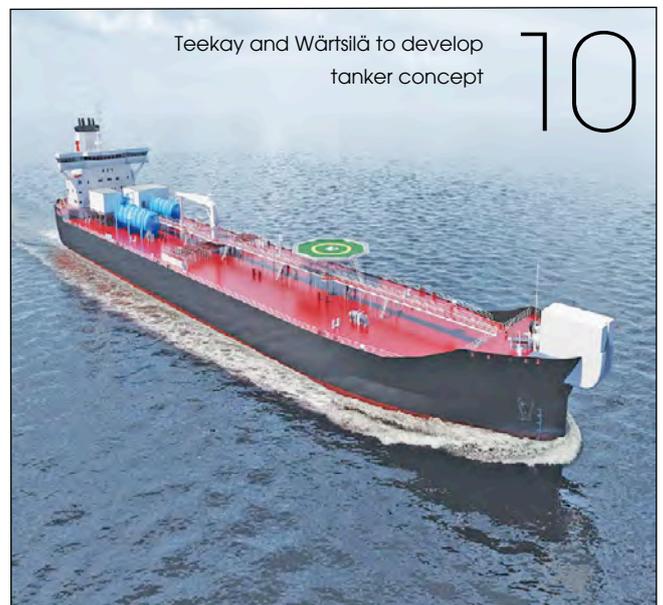
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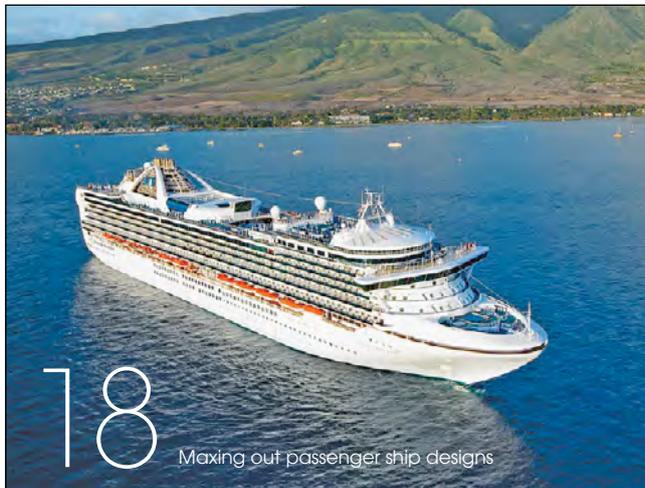
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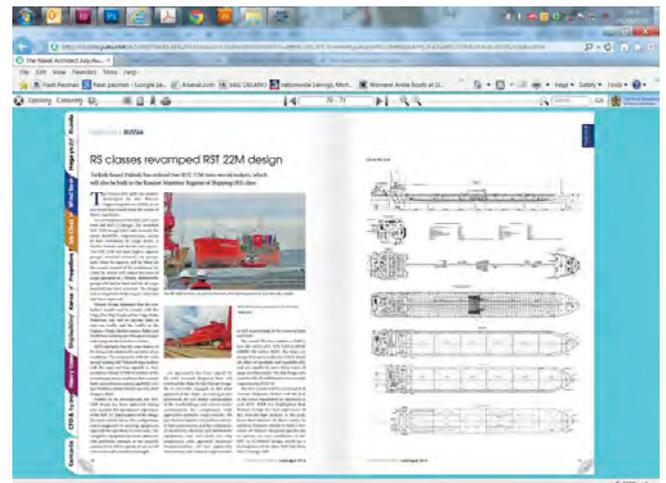
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## Room for improvement

The reality of cramped engine rooms is seldom appreciated by naval architects

As I write these words it's a year almost to the day since I took over stewardship of *The Naval Architect* and I'm still struck as to how different the world of ship design and technology is to that of safety at sea, the focus of the magazine I previously edited. Indeed, this is the first issue I've had any cause to make reference to IMO's International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), despite the fact it was a monthly occurrence on my earlier title.

Perhaps one shouldn't be surprised; after all, debate continues more than a century later as to whether the *Titanic* disaster, which led to the signing of the first SOLAS treaty in 1914 (one acronym at least which manages to be *lingua franca* across the maritime community), was the consequence of structural or navigational failings. Researchers seem to have little difficulty in finding evidence to support either argument – what psychologists would call confirmation bias.

Engineers would of course much sooner have quantifiable metrics, which may go some way to explaining why serious regard to ergonomics still struggles to gain a foothold when it comes to ship design. The research conducted by ergonomist Dr Steven Mallam into seafarer movements onboard a vessel and his development of a prototype software platform with which these might be factored in during the early design phase (p.22-25) included some revealing insights into the attitudes of naval architecture and ocean engineering students who participated in a trial. Many felt that

consideration of ergonomics was more like an optional extra if they had any time left over, and was counterintuitive to basic project goals.

To encounter such cynicism among young naval architects who in most cases will not even have started their professional careers has to be a concern, although as Mallam himself points out there's little point minimising the seafarer's risk of a work-related injury if the ship itself is structurally unsound. However, adopting a purely utilitarian perspective, macroeconomically speaking, becomes a problem when one considers the industry-wide challenge of crew retention and the need to persuade skilled young people to go to sea. In the future, as ships grow ever more advanced, financial reward alone may not be sufficient to compensate for weeks on end spent in a cramped working environment.

The obvious temptation is to lay the blame at the door of the merchant shipowner, who naturally wants to optimise their ship's cargo-carrying potential while fulfilling compliance obligations (or those likely to take effect in the foreseeable future). But they may be only as knowledgeable as the advice they receive from shipbuilders and designers. Yards and architects look in turn to guidance from the classification societies, who then refer to IMO's regulations. But between the interests of Common Structural Rules and EEDI on the one side and STCW and MLC (the Maritime Labour Convention) on the other there seems to be little common ground and it will take joined-up thinking to bridge that divide.

At the moment, the emphasis remains on bestowing 'cognitive abilities' upon the new generation of smart ships such as the SDARI-designed bulk carrier *Great Intelligence* (p.34), the first Chinese vessel to receive Lloyds Register's notation for a cyber-enabled ship. While not strictly speaking a remote-controlled or autonomous vessel (despite some occasionally confusing publicity) its AI software enables the ship to learn from historical data to generate new solutions. Perhaps the most interesting facet of *Great Intelligence's* development is the reciprocal relationship by which LR's cyber guidelines have been refined and adjusted by what has been learned during its design and construction.

Given the many projects and innovations we endeavour to reflect in the pages of this magazine it's worth remembering that many never get beyond the conceptual stage, or even publicised at all. A number of you responded to my request for more reader feedback a couple of months ago and, following on from a news item we ran last month on LR's approval in principle for a ballast-free LNG carrier, I was delighted to receive an email from former DNV surveyor Jan van der Schans about a very similar concept he pitched to his managers some 37 years earlier (p.49). Hopefully we can make 'Letters to the Editor' a more regular feature in the months ahead; Jan's account is a salutary tale of how good ideas can sometimes fail to gain traction despite their obvious potential, and a timely reminder that there should always be room for improvement. *NA*

Denmark

## Nor-Shipping targets Denmark with Opening Oceans Conference

In a first for Nor-Shipping, the conference producer has announced an event outside of its home country of Norway – the Opening Oceans Conference in Copenhagen, Denmark. Scheduled for the 2nd and 3rd May, the event will intentionally run parallel to Danish Maritime Days, and will ultimately feed into next year's Nor-Shipping conference.

Beyond the shipping focus of its parent conference, Opening Oceans will consider the future of what Sofia Furstenburg, OOC strategic lead, dubs the “ocean economy”: a constellation of businesses, particularly those focused on energy creation, and the logistical solutions that support them, which offer novel opportunities for sustainable value creation. Supported by the Norwegian Shipowners Association and Danish Shipping, the event will highlight opportunities available within the Nordic countries, particularly Denmark, a growing industry player.

The event is framed around the prediction by speaker Claire Jolly of OECD that value creation at sea will double by 2030, as traditional businesses like bulk shipping are complemented – and disrupted – by the growing renewable energy and offshore food production sectors, as well as the initial phase of underwater mining development. Speaking at a press preview, Furstenburg confirmed that OOC 2018 will be arranged into four key areas: data value, energy and minerals, mariculture, and logistics. The role of governance in these sectors will also be considered.

Alongside Claire Jolly, the event will feature Statoil's senior VP of corporate sustainability Bjørn Otto Svedrup, Maersk Group vice CEO Claus V. Hemmingsen, and Danish Ship Finance's head of research Christopher Rex, amongst others from CorPower, the UN, and GMT.

Opening Oceans will invite maritime business leaders to consider new opportunities in the ocean economy



Commenting on the forward-looking theme of the event, Furstenburg commented: “Nor-Shipping is evolving, just as maritime will, to build on its established position and access new opportunity. We want to help industries, and the next generation of business leaders, seize the potential that is out there.”

LNG

## Foreship becomes full SGMF member

Finnish naval architecture firm Foreship has announced that it is now a full member of the Society for Gas as a Marine Fuel (SGMF), a London-based body working to encourage the uptake of LNG in the maritime industry. Foreship will be joining over 125 members, amongst them shipowners, classification societies, manufacturers, and designers.

Describing itself as the “leading industry resource for pooled knowledge and experience,” SGMF helps smooth the transition to LNG for shipowners by organising work groups, publishing bunkering guidelines, offering competence training, and providing financial and technical advice. In particular, it looks to make sure that LNG use grows sustainably.

The flourishing of LNG in recent years has seen Foreship take on more newbuilding and conversion projects that use gas as a fuel source. With this in mind, Olli Somerkallio, Foreship Head of Machinery, commented: “Foreship has considerable knowledge and experience in the use of LNG onboard ship to contribute to SGMF and, as we expand our machinery division, membership is a way of demonstrating our commitment to the development of LNG as a marine fuel and participate on a formal basis in wider industry initiatives.”

Market

## Rolls-Royce commercial Marine

Rolls-Royce announced in January that it intends to streamline its business structure, consolidating its five current operating businesses into three units: Civil Aerospace, Defence, and Power Systems. In tandem with this simplification, the business has committed to review its struggling Commercial Marine division, which has reportedly faced “weak demand for products and services,” driven by the downturn in its core market, offshore oil and gas.

The company's simplification exercise will see their Naval Marine and Nuclear Submarines divisions incorporated within Defence, while Civil Nuclear operations will become part of Power Systems. The

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exact reorganisation is yet to be confirmed, however, with Rolls-Royce stating that they “are in the process of defining this restructuring and further details will be given at the time of our 2017 financial results on 7 March 2018.”

As for Commercial Marine, Rolls-Royce has clearly stated its intention to review the division this year, and appears to be considering the idea of a sale. Warren East, Chief Executive, said: “This is the right time to be evaluating the strategic options for our Commercial Marine operation. The team there has responded admirably to a significant downturn in the offshore oil and gas market to reduce its cost base. At the same time, we have carved out an industry-leading position in ship intelligence and autonomous shipping and it is only right that we consider whether its future may be better served under new ownership.”

#### Tankers

## Teekay and Wärtsilä to develop tanker concept

Maritime transport giant Teekay have partnered with Finnish solutions provider Wärtsilä to develop a new shuttle tanker concept that will utilise an array of Wärtsilä technology in a bid to achieve optimal economic and environmental efficiency.

Teekay’s confidence in this “next generation” concept has led to their ordering of a quartet of the vessels, to be built at the Samsung Heavy Industries yard located in South Korea. Signed off in December and January, the orders are reportedly worth over 110 MEUR.

Central to the concept is its Wärtsilä 34DF dual-fuel engines, which will primarily run on LNG but can also be powered by recovered Volatile Organic Compounds – a source of fuel which is usually left to evaporate and is subsequently vented to the atmosphere, resulting in both economic and environmental losses. With Wärtsilä’s VOC system, however, the gas can be recovered, liquefied and stored, ready for use in tandem with LNG.

According to Wärtsilä, this will lead to reduction of NO<sub>x</sub> emissions by upwards of 80%, and particulate emissions by more than 95%. SO<sub>x</sub> emissions, they claim, will be “almost entirely eliminated.” On top of these technologies, the shuttle tanker will also feature the Wärtsilä Hybrid system, which employs batteries to optimise a variety of power distribution tasks, Wärtsilä cargo and ballast pumps, and an inert gas generator.

Indicative of Wärtsilä’s “Smart Marine Ecosystem” philosophy (as discussed in January’s *The Naval Architect*) and current innovation in cyber-enabled ship design is the added inclusion of an



The suite of Wärtsilä technology aboard the vessel places it at the forefront of shipping innovation

Eniram Vessel Performance Management system. Developed by Eniram, a company owned by Wärtsilä, the data collection platform will encourage further operational efficiency by analysing various aspects of vessel performance in real time and providing reports to crew to aid decision-making.

#### Cruise

## Carnival confirm 2018 launch of cruise quartet

Miami-based Carnival is eagerly anticipating the launch of four new cruise ships this year, to operate under its Carnival Cruise Line, Seabourn, AIDA Cruise and Holland America Line brands.

Comprising *Carnival Horizon*, *Seabourn Ovation*, *Aidanova* and *Nieuw Statendam*, the quartet will offer 3,600, 600, 5,230, and 2,666 berths respectively. First to arrive in April will be the 133,500 GT *Carnival Horizon*, built by Fincantieri at their Marghera shipyard. This will be followed by *Seabourn Ovation* in May, and then the remaining two ships in December.

Reflecting the global span of Carnival’s brands, the ships will operate on a variety of routes, ranging from the Caribbean to the Norwegian fjords. Equally diverse is the design of each ship and their on-board amenities; the family-friendly *Carnival Horizon*, for instance, will offer a Dr. Seuss WaterWorks aqua park, while *Seabourn Ovation* will look to tempt discerning travellers with contemporary interiors and private verandas.

Of the quartet, *Aidanova* offers the greatest technical interest as the first cruise ship fully powered by LNG both in port and at sea. In a show of confidence for LNG, Carnival state that *Aidanova* will be the first of a total of seven LNG-powered ships to be delivered by 2022 for Carnival. Including these six additional LNG vessels, Carnival are set to receive a total of 18 unidentified ships in the next four years. **NA**

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# Shipping's green charm offensive

With the 2020 sulphur cap looming, an environmentally-minded coalition has pressed the IMO to ensure global compliance. Malcolm Latache considers their proposal

Last summer, BIMCO, ICS, INTERTANKO and INTERCARGO jointly submitted a proposal to the IMO on the subject of reducing shipping's CO<sub>2</sub> emissions. Specifically, the four bodies asked the IMO to take measures to maintain international shipping's annual total CO<sub>2</sub> emissions below 2008 levels, and to reduce CO<sub>2</sub> per tonne/kilometre, as an average across international shipping, by at least 50% by 2050, compared to 2008. The proposals are expected to be discussed at MEPC 72 in April 2018 along with others that propose even deeper reductions up to as much as 90%.

Seven months down the line, in January this year, an even larger coalition of bodies is calling for more IMO regulation related to emission controls. Joining the first three bodies named above are the Cruise Lines International Association, International Parcel Tanker's Association and World Shipping Council, along with the Clean Shipping Coalition, and WWF Global Arctic Programme, Friends of the Earth US, and Pacific Environment. Since the joint announcement, other bodies including Maersk and Danish Shipping have expressed support for the proposal.

Although the announcement was made in January, the submission was actually done in November last year and will first be actioned at the IMO Sub-committee on Pollution Prevention and Reduction (PPR5) meeting in early February. Thereafter it may well pass for further discussion at MEPC 72.

This time around the subject under discussion is SO<sub>x</sub>, and the call is for a complete ban on ships that carry as fuel anything that does not comply with the requirements of the 2020 0.5% global cap on sulphur. The only exception permitted would be for ships which are fitted with a certified exhaust gas cleaning system.

Behind the call for a ban is the usual fear that unscrupulous owners will find a way of circumventing the 2020 requirement to the detriment of more honest operators. In the announcement the parties involved said that the 2020 sulphur cap will provide substantial environmental and human health benefits but, at the same time, will significantly increase ships' operating costs and will present major challenges to governments that must ensure consistent enforcement across the globe.

To secure the intended environmental and health benefits, the organisations say it is of utmost importance that enforcement of this standard is efficient and robust globally. Any failure by governments to ensure consistent implementation could also lead to serious market distortion and unfair competition.

The January announcement, coupled with the positioning on CO<sub>2</sub> reduction last year, is likely to show shipping in a good light. Furthermore, if the proposals are not adopted by the IMO, then the industry could identify as the villains of the piece those IMO member countries that voted against it. However, the charm offensive does provide cover for some questioning about potential problems.

Studying the proposal in full it is clear that the bodies behind the latest initiative are a little more pragmatic than the announcement might at first suggest. While the proposal to PPR5 does indeed state that non-compliant fuel should not be permitted and includes a revised wording for the current rules, it also recognises the difficulties that may arise in practice. Within the document, the co-sponsors say that they have on several occasions and in multiple submissions expressed their concern with various transitional issues that may arise and list at least four of those possibilities:

- regional or local non-availability of compliant fuel oil;
- impact on fuel and machinery systems resulting from the use of low sulphur fuel oils;
- verification issues; and,
- control mechanisms, and actions that are necessary to ensure compliance and consistent implementation.

As well as identifying some of the issues, the proposal calls for a set of guidelines covering non-availability and the need for a global Fuel Oil Non-Availability Report system accepted and managed by port states; fuel quality issues, particularly regarding new types of fuels and blends, including development of standards in cooperation with ISO; verification issues, control mechanisms, and actions that are necessary to ensure consistent implementation and compliance plus ways of establishing that fuel is as stated on bunker delivery notes; and sampling and testing methods for establishing sulphur levels.

Calls for consistent enforcement are all very well but as the IMO has pointed out on several occasions it is for flag and port states to police and enforce the regulations. Just as with any other maritime regulations there are some nations that rigorously enforce IMO rules and many that do not. In addition, the delegates that vote at the IMO may not be in a position to dictate to refiners and suppliers.

In the long run it is for those latter organisations to determine what they are able and prepared to supply and they will probably not be very troubled if it means shipowners in need of fuel will not meet a rule they did not make. *NA*



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## Ballast water

## Aqua-tools B-QUA users to receive free training

French water microbiology specialist Aqua-tools has promised a year's free training and support to users of their B-QUA rapid ballast water monitoring kit.

The kit is designed to help shipowners, crew, and port state control inspectors determine whether a ship's ballast water is compliant with BWMC discharge standards whilst on board, eliminating the need to send a sample to a laboratory and providing quick insight into the effectiveness of a vessel's ballast water treatment system. This is made possible through the use of ATP (adenosine triphosphate) sampling, an indicative method which does not count the number of organisms in a sample but instead determines biomass and/or viability by detecting cellular energy.

Aqua-tools will offer training for crew and technicians in both online and on board settings, recognising outcomes with certificates and training reports. The company also plan to provide sampling recommendations, regulatory updates, and copies of scientific studies to keep users informed of the latest developments in ballast water management.

With this provision of support, Aqua-tools appears to be making an effort to encourage wider implementation of ATP-metry testing across the maritime industry. Maritime has lagged behind other industries in the uptake of water microbiology, largely due to the delays in implementing the Ballast Water Convention, which finally came into force last September.

Marc Raymond, CEO, confirmed Aqua-tools's offering: "Based on our success in supplying quick water monitoring test kits to other industrial sectors, we are now able to provide similar scientific expertise to the maritime industry, within the framework of risk and quality management. Despite constantly changing regulatory requirements and technologies, Aqua-tools's Rapid Microbial Solution provides the global shipping industry with protocols adapted to their products and processes, as well as the extensive support water sampling and testing requires."

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## Lubricants

## DNV GL to study EALs after stern tube failures

DNV GL, in partnership with insurers The Swedish Club, Norwegian Hull Club, Gard, and Skuld, has set in motion a joint development project to test the performance of Environmentally Acceptable Lubricants (EALs) amid suggestions that they are



Bearing failures require timely – and costly – repairs to the propeller stem tube

responsible for the recent upsurge in stern tube bearing failures.

An alternative to mineral oils, EALs have seen increased application following 2013 regulations requiring commercial vessels trading in U.S. waters to use Vessel General Permit compliant lubricants below the waterline, meaning they should be biodegradable, minimally toxic and not bioaccumulative.

Testing organised by DNV GL will be carried out by Leonardo Testing Services Ltd. at the University of Sheffield, which has developed state-of-the-art non-invasive techniques to examine the behaviour of lubricants in real time. In particular, the researchers will analyse oil film thickness under varying loads and temperatures, and hydrodynamic oil film formation, to get a clearer picture of EAL performance.

DNV GL says the project represents a much-overdue foray into EAL research. Øystein Åsheim Alnes, principal engineer at DNV GL explains: "Very few studies have been conducted to compare the lubrication performance of EALs with that of traditional mineral oils in stern tube applications. With this new study we hope to gain a better understanding of factors influencing the lubrication performance of EALs."

The announcement has been welcomed by manufacturers of seawater lubricated propeller shaft bearing systems, who claim their technology eliminates the need for shipowners to use EALs. Terry McGowan, CEO of Canadian company Thordon Bearings, which has been calling for more research into EALs since 2015, says the initiative comes at a critical juncture for the maritime industry: "Ship operators are beginning to spurn mineral oil-based lubricants in favour of cleaner, more reliable alternatives, but as yet there is little evidence to indicate that EALs can do what they're supposed to do without damaging machinery or the environment."

Addressing what he sees as the reason behind EAL failures, McGowan adds: "The real concern is when biodegradable oils mix with water. Their viscosity can

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deteriorate with water ingress, resulting in reduced lubricating capacity and potential damage to seals and bearings. One easy solution for newbuildings is to use an open seawater lubrication system.”

However, there are no plans for the project to compare the performance of EALs with alternative lubricant solutions. DNV-GL's results are expected to be published later this year.

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#### Artificial Intelligence

## Transas launches AI package for THESIS

Navigational and operational technology specialist Transas has announced the release of a package of AI applications for its THESIS platform (Transas Harmonised Eco System of Integrated Solutions).

Dubbed the 'A-Suite,' the package contains an array of applications that use artificial intelligence to reduce risk at sea by identifying human or vessel behavioural anomalies and warning of potential consequences, as well as making suggestions for route and performance optimisation.

Initially, the package will consist of three 'core modules.' The first, Advanced Intelligent Manoeuvring (AIM), is an anti-collision tool which uses historical data on ship operating behaviour in the same location, plus a digital hydrodynamic model of the vessel, to warn of potentially poor judgement by officers. The second, Advanced Intelligent Diagnostics (AID), is designed to detect anomalies in manoeuvring patterns, for instance in rate of turn, and provide decision support. It collects data using a network of sensors, and offers both real-time and post-voyage analysis. Finally, Advanced Intelligent Routing (AIR) uses parameters to optimise voyage planning and routing, taking into account anticipated traffic, metocean data and hazards.

Also available in the package are the Advanced Data Delivery (ADD) and Advanced Remote Maintenance (ARM) solutions. The former takes away the onus on officers to update SENCs and weather data, as well as generating a navigational audit trail to ensure compliance, whilst the latter provides remote diagnostics and vessel performance analytics. ARM also backs up vessel software parameters in the cloud, to ensure a quick restoration after a system failure. An e-learning portal, Advanced Remote Training for Seafarers (ARTS), is also on offer, providing access to type-specific training courses for personnel.

As a cloud-based platform THESIS, and therefore A-Suite, can be accessed at sea and on shore, facilitating data sharing. Transas CEO Frank Coles said: "When we first started to envisage how ships would

be operated in the future, we realised there would be much greater collaboration between ships, back-offices, traffic control centres, etc. With A-Suite we set out to build a set of intelligent decision support tools for working in this shared environment.”

In the event of connectivity failures, THESIS is kept operational via a pre-processing data management server. The system delivers data through encrypted channels, too, avoiding email's security vulnerabilities.

[www.transas.com](http://www.transas.com)

#### Monitoring

## WinGD launches WiDE system to leverage data

Engine developer Winterhur Gas & Diesel has announced the release of its WinGD Integrated Digital Expert (WiDE), a system designed to collect and analyse ship data in order to predict component failures and optimise performance.

WiDE comprises of a physical data collection and monitoring (DCM) unit, engine diagnostic system (EDS) software package, and access to WinGD remote support. The DCM is responsible for collecting engine and other machinery data, which is then analysed by the EDS in order to anticipate possible component failures and generate insights for crew. If assistance or troubleshooting is required, crew can contact WinGD's external support service via the system and discuss issues in real time with advisors. The data collected by WiDE is also automatically transferred, via a secure server, to shore-based shipowners and fleet management so they can keep abreast of developments on board their vessels.

In a video released to promote WiDE, WinGD claim that the system offers an array of benefits, including reducing unplanned stoppages, predicting and extending the time between component overhaul, providing access to spare parts, and saving fuel by optimising engine performance. With an eye towards these benefits, WinGD's general manager of business development, Carmelo Cartalemi, stated: "With WiDE we are able to utilise the power of the machinery data in combination with our engine expertise and advanced data analytic techniques. This allows us to support shipping companies during their day to day operations with valuable insight. We provide live troubleshooting support for engine performance, suggested maintenance, and component replacement, reducing operational interruptions.”

As of January this year, WiDE will be installed on all contracted new WinGD engines. The system can also be retrofitted to older engines, provided they are electronically controlled.

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# Maxing out passenger ship designs

Whether it's newbuilds in a series or a conversion, adding capacity to existing designs is no quick fix, write Kari Reinikainen and Alan Lam

**A** look at deck plans of ships in the brochure of a cruise line often reveals designs that have been 'maxed out' by adding an additional deck with cabins or lengthening the hull of later units of a class of otherwise similar ships.

While 'maxing out' means that some design work does not need to be done, quite a few things change, and significant design work is still needed to ensure that everything will continue to work as it should, under every circumstance.

Generally speaking, adding a deck to a vessel will increase resistance more than lengthening the vessel would, says Marit Holmlund-Sund, senior manager of marketing and communications at Finnish technology company Wärtsilä. "Lengthening the hull may even reduce the resistance.

However, this is a general statement; each hull is different and the change in resistance that would follow the addition of a deck or lengthening the hull has to be checked in each case," she comments.

However, adding capacity to later units of a series of passenger vessels does not necessarily require more propulsion power. Holmlund-Sund comments: "The power plant is designed so that the vessel will meet the trial speed, which has been specified in the building contract." As such, because ships do not operate at this speed in normal service, but at a lower speed, there is some reserve power in the design of each power plant.

## Notable redesigns

Examples of baseline vessel designs that were later lengthened include Royal Caribbean

International's Voyager class that was built in Finland at the turn of the millennium: each original ship had a length of 311m and capacity for about 3,100 passengers. The stretched Freedom class that followed in 2007 is 339m in length and can accommodate 3,600 passengers.

TUI Cruises, the German premium market operator, decided to increase the length of its two final newbuildings in a series of six ships, also in Finland, by about 20m from the 297m of the first four ships. This will add 180 cabins to the two final newbuildings, which will have accommodation for 2,894 passengers and enter service in 2018 and 2019, respectively.

Building later units of a class of ships longer than the original design raises a number of structural and stability issues, notes Finn

The design of the 1998-built *Grand Princess* (below) was later scaled up for the *Caribbean Princess*



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Wollesen Pedersen, CEO of the Danish consultant architects Knud E. Hansen. The company has been involved with the cruise industry since its inception in the late 1960s and the ships it designed for companies like Royal Caribbean Cruises Ltd (RCCL) and the then Norwegian Caribbean Line (now Norwegian Cruise Line) played a pivotal role to launch the industry in its present form.

“Many ropaxes are designed with lengthening later in mind,” Wollesen tells *The Naval Architect*. “In addition to global strength of the hull, fire zones come to the spotlight when a vessel is being lengthened, be it an existing vessel or a design that is on a drawing board. The zones will change as the vessel becomes longer.

“When you add an additional deck, stability also becomes an important matter, because it will move the centre of gravity of the vessel upwards,” Wollesen continued. “The deadweight capacity of the vessel may increase in the process, provided that the scantlings have been prepared to take more buoyancy.”

### Capacity of shipboard systems

Whether lengthening or adding a deck, a further challenge emerges from shipboard systems. An additional cabin deck on a major cruise ship can add 500 lower berths to its capacity and a few thousand gross tons to the vessel. A longer hull has similar effects, depending on the additional length.

“All systems for environmental technology, processing waste water, food waste and garbage, are designed for the number of people aboard the ships. There may be some overcapacity in such systems to accommodate a certain increase of passengers, but in many cases, it will require upgrades such as increased tank capacities, process volumes, increased capacity on pumps and other process equipment to handle larger flows,” says Henrik Badin, CEO of Scanship Holding, a Norwegian company that supplies solid and liquid waste treatment systems to ships.

The capacity of shipboard systems, ranging from power supply to HVAC, on board store rooms and waste handling all need to be looked at. “Black water capacity is an example of what needs to be thought of: you cannot pump it to the sea near a coast,” Wollesen points out. The layout of the sprinkler system must also be reviewed.

The shipboard systems also have to work properly in emergency situations on a ship that is larger than its baseline design. “When you add capacity to a vessel, you need to rethink the entire safety strategy,” Wollesen continues.

Wollesen worked as project manager of HVAC of Princess Cruises’ 2,600 passenger capacity *Grand Princess* of 1998, a baseline design that was itself ‘maxed out’ in 2004 by the 3,100 passenger *Caribbean Princess* that has an additional deck of cabins. The former vessel uniquely had its Safety Management System tailored beyond the rules and regulations as they stood at that time.

Wollesen says: “A lot of effort and resources were used by yard, suppliers and owner on the task... On that ship, the hallways and corridors were overpressurised by the air conditioning system in case of a fire in a cabin, to keep the smoke in the cabin.” With their larger capacity, later units of the same class required an assessment of the air conditioning system, to ensure that it could perform this same procedure in a cabin fire emergency.

On the other hand, optimising the capacity of onboard systems does not necessarily mean maximising them, and there remains the prospect of increasing the capacity of a ship design – or later units of the class – at some point in the future if the owner believes this is a viable option. “If the systems are not optimised to meet the demand on board, they will not be energy efficient,” Wollesen pointed out.

### Quicker than starting from scratch

From a financial point of view, lengthening an existing ship can cost almost as much as a newbuilding, but the former allows the owner to get additional capacity much quicker than if a newbuilding was ordered.

Increasing the capacity of later ships in a series means increasing the revenue base without a need to start from a scratch with an entirely new design. However, significant work is still needed on the design side, irrespective of whether an additional cabin deck or lengthening was opted for.

From a passenger point of view, the latter option offers an advantage: it means increasing both the outdoor deck space and indoor public areas. This is not the case with

additional cabin deck: balconies of cabins are virtually the only additional outer deck space that results, while the indoor public areas do not increase, yet have to be shared with more passengers.

As cruise lines have become more flexible in integrating the outer decks and adjacent service areas like bars and buffet restaurants, earlier used only in the daytime, to the evening programme on board, the need for additional public areas to respond to higher passenger load has been partly mitigated.

### Insufficient outdoor deck space

While there is heavy demand for outdoor deck space on cruises in warm regions in particular, designers of large cruise ships have taken different approaches towards providing it in the recent past. On some vessels, the boat deck level is almost entirely out of bounds for passengers, which means that the pool deck areas that are usually located high up in the vessel must satisfy this demand.

However, it would seem that designers are waking up to a need to provide outside deck areas not just for sunbathing but also for facilities such as restaurants and bars. This has resulted in a number of vessels that have several of these outlets at the boat deck level. The Breakway and Breakway Plus series – in which a cabin deck was added to the earlier baseline design – of Norwegian Cruise Line, and *MSC Seaside* of MSC Cruises (which boasts the highest ratio of outdoor space of any cruise ship at sea) are examples of such designs.

The new, larger locks of the Panama Canal have removed the need to confine the beam of cruise ships to 32.3m (the maximum width of the old locks), although cruise liners wider than this have been built since the late 1990s. Wider hulls mean more space inside and a greater outdoor deck area as well.

However, as inside cabins fetch the lowest price, the additional space on cabin decks that can follow from wider hulls is not a major advantage. While technical areas, like piping and ducting can be placed here, the cabin block above the hull is actually slightly narrower than the hull itself on many recent ships and the superstructure widens again further up on the pool decks. *NA*

# A design for working

Why does ergonomics still struggle to be taken seriously by ship designers?  
*The Naval Architect* looks at recent work to create a shared platform that gives greater emphasis to the end-user experience

Nearly 70 years ago a meeting was held at the Admiralty in Whitehall, London. It was the brainchild of Hywel Murrell, a chemist by education, but whose wartime work with the army and navy had made him acutely aware of the value of human factors research. In 1948, Murrell had been appointed head of the Naval Motion Study Unit, but he wanted to go further and bring together like-minded people engaged in related research in the fields of applied psychology, physiology and anatomy and movement study. That meeting led to the formation of the Ergonomics Research Society – today known as the Chartered Institute of Ergonomics and Human Factors – and a new word (although first coined by the Polish inventor Wojciech Jastrzębowski almost a century earlier) entered the English lexicon.

Human factors and ergonomics (HF&E) is such an implicit part of everyday life that it often passes unnoticed, but given its founder's background in naval research it's perhaps surprising that the subject isn't treated more seriously when it comes to ship design, at least where that concerns merchant vessels. Despite research that has repeatedly stressed the challenging environments and risks crew must deal with onboard modern ships, which have not been optimised to meet their needs, the 'end-users' of the design frequently find themselves subordinate to the requirements of other stakeholders, in particular the shipowner. Moreover, the value of HF&E is often questioned by the designers, who often treat it as an afterthought.

Is this a question of market forces or a more systemic educational failure? According to ergonomics expert Dr Steven Mallam, now a post-doctoral fellow with University College of Southeast Norway's maritime sciences faculty, it's a little of both. He explains: "It's not the actual need for radically new or cutting edge knowledge, but rather the more application of knowledge we already possess.

"My rationale is that if you make human-centred design and ergonomics application easier and more intuitive for



Dr Steven Mallam

engineers to actually understand and use, through better, more usable methods and tools, then ultimately they will more readily adopt them in their work practices. If naval architects see the added value and are able to implement it into their design processes then they will hopefully utilise them in an effort to create a competitive edge in the marketplace."

## Cultural differences

Mallam spent five years engaged in PhD research at Chalmers University of Technology, Gothenburg, exploring how ergonomics might be more effectively integrated into ship design; a project sponsored by the Swedish innovation fund Vinnova and the Swedish Mercantile Marine Foundation. One of the main focuses of his work has been how best to bridge the cultural differences between naval architects and seafarers, given their distinct educational backgrounds, work demands and technical language. Typically, says Mallam, ship designers have little to no understanding of the operations at sea and the demands on the end-users.

Moreover, regulatory support for HF&E tends to be weak, with a tendency more towards non-mandatory guidelines than specific requirements. Mallam observes:

"There are actually quite a lot of guidance notes for design aspects of the ship – bridge, maritime equipment, although less so for the engine room and engine control room. However, the quality and actual value of these various guidelines is up for debate, and can arguably be heavily criticised."

This lack of ergonomic understanding in the guidelines, according to Mallam, means the benefits of integration are rarely understood by shipowners. "They may look at it as unnecessary added costs in the upfront design and delivery of a new vessel – thinking that if it is not in the regulations then it can't be that important. Of course, this is not accounting for lifecycle costs and the added value of ergonomics in design throughout a ship's operation."

The challenge therefore is prove the added value ergonomics can offer to traditional design processes, something Mallam does not think can be realised without first facilitating an attitude change. Interestingly however, his thoughts underwent something of a reversal during the course of his research.

He explains: "At the beginning I argued for a top-down approach for implementing ergonomics into ship design – to establish mandatory regulations from the IMO which required shipbuilders to follow specific criteria. However, by the end of my research I was much more interested in a bottom-up approach – developing engineering education and naval architecture design methods and tools that facilitate human-centred design."

## Rethinking ship development

It was this which led Mallam to become interested in the possibilities that might be afforded by knowledge transfer models. He concluded that the most effective means for promoting better communication among stakeholders was creating a platform that would allow for a more participatory design process, whereby the end user (i.e. the seafarer) could provide feedback directly to production engineers and designers. This inclusive environment would allow for problems to

be identified early in the design process and optimal solutions developed that would allow for more effective ergonomic design.

While CAD, computer simulations and brainstorming sessions have all been explored as options in past research, there has been a tendency to focus on more general or critical issues such as mass evacuation and crew movement around the vessel. But Mallam believed closer analysis of GA ship sketches and layout drawings could allow for more effective HF&E integration when applied to specific crew work tasks.

The engine room in particular was identified as a problem area; typically there is a tendency to minimise the physical footprint of this space because it impacts upon the ship's cargo-carrying capacity, but in doing so this also detracts from the crew's ability to move freely and safely around what is a labour-intensive environment.

For a case study, Mallam and his co-researchers undertook detailed analysis of a ro-ro cargo ship (GT: 23,128, LOA: 191.8m, Breadth 26.4m, Draft: 7.8) over an eight-day period while it was operating in the Gulf of Bothnia, Baltic and Kattegat Seas. Field data collection took a four-pronged approach:

- A holistic picture was built up of the work environment in pertaining to the engine rooms. This included detailed documentation of all equipment and a cataloguing of the basic physical characteristics of each identified area, including passageways and access points.

- The next phase considered how accurately this real environment was reflected in the conceptual drawings of the original GA and the detailed machinery arrangement held by the shipping company.

- To complement these and gain a more comprehensive perspective of the work environment the entire engine crew were interviewed and job shadowed throughout the eight-day period.

- To build up a generalised summary of the activities performed by crew, as well as their frequency and importance, the researchers used an evaluation tool known as link analysis, which is more commonly found in interface design. Crew movements were mapped against the GA drawings, and compared against the onboard analysis and interviews with the crew to reveal the benefits and drawbacks of GA drawings (see Figure 2).

It was found that while the GA captures the essential elements such as the hull structure, scantlings, clearance levels and emergency exits, an abundance of auxiliary equipment and installations will not be represented. What in the conceptual stage appeared to be adequate space becomes compromised, impeding access, restricting the true working area and creating numerous safety hazards. Of course, a naval architect should always make provision for structures in their design but very often these 'placeholders' on the drawing are not representative of the final construction.

Consequently, Mallam and his colleagues discovered that the working environment is often actively modified.

"The workaround solutions are always quite interesting and sometimes very concerning from the personal and team safety perspective of the crew," he explains. "The best example I have was the maintenance of a fuel oil (FO) separator... The cleaning area was well designed, had proper ventilation, drainage, protective screens, PPE, etc. but was not in close by. Because of the distance and obstacles in their way they chose to clean the dirty parts next to the FO separator, bent over small buckets of diesel oil (which was subsequently spilled all over the floor). Furthermore, the cleaning area was barely ever used because of its poor proximity to key equipment and machinery around the engine room."

Other notable examples Mallam has encountered include cutting through engine room decks to help with the movement of equipment parts, or the hatch placement when the original becomes inaccessible after piping is installed. In another case, the crew created a makeshift locker room beside the engine room to store spare clothes and personal protective equipment because it was considered a far better option than the purpose-built locker room and showers three decks below.

It's tempting perhaps to attribute the blame to poor design but Mallam is quick to stress that installation of equipment at the shipyard also determines the quality of the finalised work environment.

He explains: "The main purpose for a seaworthy ship is that the hull and overall structure is stable and safe. The details of the working environment and factors such as ergonomics are obviously of less concern than the overall safety of the structure at sea. Thus, it is easier for the industry, regulatory bodies, etc. to overlook these, by comparison, smaller issues. How shipyards coordinate throughout construction, and how ergonomics applications can be implemented on-site throughout construction at shipyards is a valuable pursuit."

Through link analysis and interviews with the crew it became clear that while there are specific routines and maintenance schedules these will vary in frequency, meaning that no two days are exactly the same. However, it was possible to identify particular nodes where work either regularly took place or served as a 'starting point' for tasks elsewhere on the

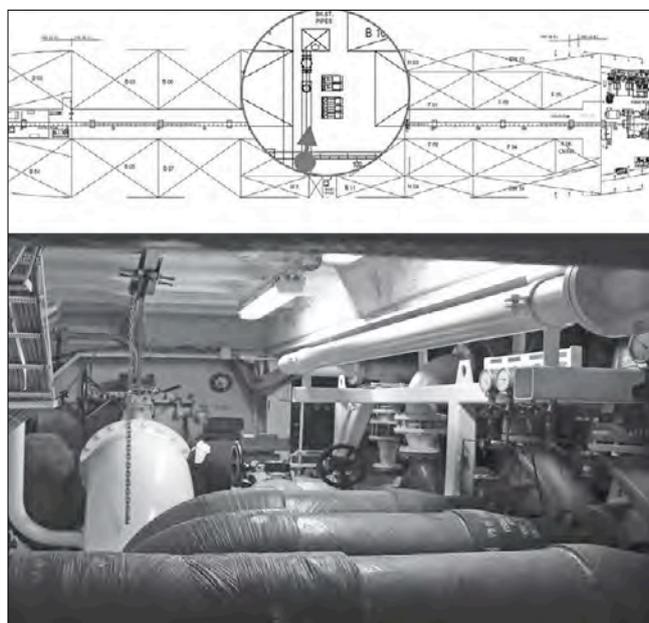


Figure 1: GA drawings can often show a marked difference to the reality onboard the fully equipped vessel

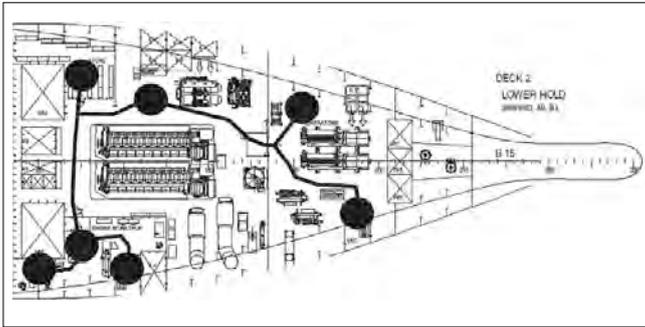


Figure 2: Link analysis of the ro-ro's workshop, storage area and entrances/exits. The black circles denote key nodes

ship, such as the locker rooms and the engine control facilities, where work is discussed and delegated. The logistics of moving equipment and stores lifted onto the ship from shore-side and down to lower decks were also carefully planned tasks requiring smooth, unimpeded transit between key nodes to optimise safety.

The crew's movements between different nodes while conducting specific tasks corresponded with a 'hub-and-spoke' model across the ships 'network', with 'hubs' being the centralised areas for key activities and 'spokes' the movements between these locations.

### Ergonomic Ship Evaluation Tool

The end goal was to develop a database for HF&E knowledge and specific end-user experience for each ship department that could be physically represented alongside the GA. However, one of the biggest challenges remained winning the support at a management level from the different stakeholders.

In order to demonstrate the benefits of integrating HF&E more clearly the team developed a software prototype, E-SET

(Ergonomic Ship Evaluation Tool), a visual tool designed to facilitate participatory design processes and knowledge transfer between different stakeholders. E-SET takes the task and link analyses stored on the database and imports them into 2D and 3D ship models, visually mapping the crew movements required for task execution. As with web mapping services, output metrics make it possible to identify 'high-traffic' areas and logistical bottle-necks on the vessel, the theory being that this information would reveal to designers those areas of the ship where obstructions (such as auxiliary equipment and piping) should be kept to a minimum.

A trial of E-SET, which can be simply installed on a standard 64-bit Windows laptop, was conducted involving final year students from Chalmers University's Naval Architecture and Ocean Engineering Master's program. As part of the trial, the students also attended a short (four hour) ergonomics workshop, which was developed to engage them in HF&E considerations ahead of the final year projects and the value of end user experience in the design process. The overall impression proved favourable, with participants scoring

E-SET highly for usability and that the 3D conceptualisation of the ship drawing increased understanding of the work environment.

However, doubts were expressed when it came to the value of integrating E-SET and ergonomics methods into actual ship design projects, with many feeling that while it might be a 'nice thing to do' it undermined their focus and purpose as naval architects, namely to work to pre-set goals efficiently and effectively. In other words, even graduate students with little real-world experience of engineering held negative impressions about ergonomics.

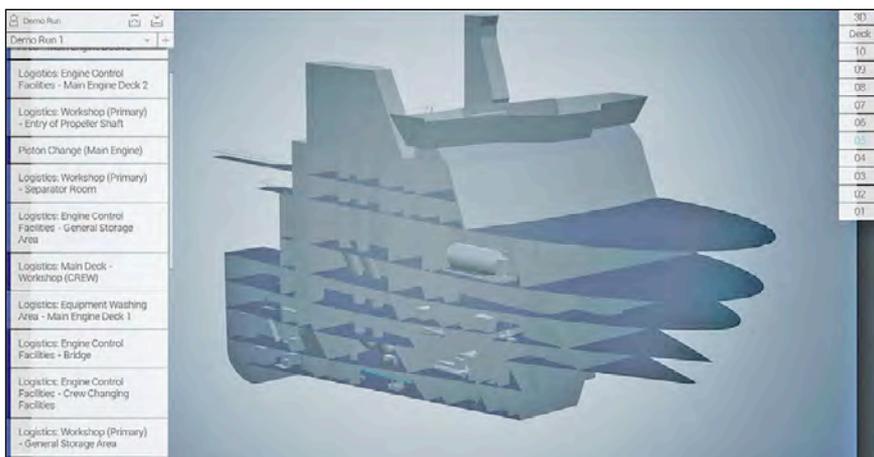
For now at least E-SET remains a work in progress but with an eye towards wider application. Mallam says: "We continue to use it as a teaching tool within the engineering curriculum and naval architect education to demonstrate end-user demands and practical human-centred design methods in action. I would like to see the functions of E-SET developed further from a commercial perspective. The philosophy and functions of E-SET have a lot of potential to add value to the traditionally engineering-focused ship design process. To have E-SET developed and commercialised as either a stand-alone product or integrated into traditional naval architecture design software is the next phase."

### Recommendations

Unsurprisingly then, one of Mallam's principal recommendations to stakeholders is that ergonomics should be incorporated into the formal curricula of undergraduate and postgraduate engineering programs. He argues in his doctoral thesis: "Ergonomics, like other engineering skills, requires a foundation of knowledge and understanding for future generations of engineers and designers to build upon. Without formalised ergonomics education within engineering curricula ergonomics will continue to be underutilised and misunderstood"

IMO also has an important role to play in formalising ergonomics within international shipping. Mallam points to the growing disconnect which has emerged between seafarer competency standards such as the Standards of Training, Certification and Watchkeeping for Seafarers (STCW) and ship design criteria and ship design criteria such as SOLAS. In this regard, he believes the development towards mandatory goal-based standards could help guide shipbuilding in improving the quality of work environments.

Figure 3: The graphical interface for E-SET showing a ship model in 3D mode



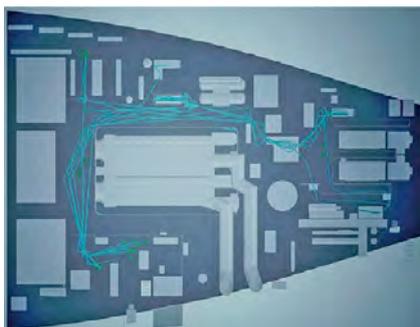


Figure 4: E-SET in 2D mode with crew task movements mapped

He adds that all stakeholders, but particularly naval architects, should spend an extended period of time onboard a ship, whether during their education or periodically throughout their career for professional development. This would provide them with context of the demands the end-user will experience when their design is put into practice.

Further, Mallam believes industry stakeholders need to be more receptive to undertaking pilot studies (such as E-SET) investigating ergonomics and participatory practices in design. He concedes however that one of the stumbling blocks remains that while studies such as his point to theoretical benefits the empirical evidence is harder to measure:

“One of my favourite quotes regarding ergonomics is from a former president of our professional association, who said ‘good ergonomics is good economics’, meaning that good ergonomics is not only appropriately applied scientific knowledge, but cost effective and practical... This is also a driving force behind how and why E-SET was developed with the particular functions and philosophy that it has.

“There has been very little quantitative data on the economics of ergonomics in the shipping domain. This is for several reasons, one being the general lack of research in the area as a whole. I can take one passage from my PhD thesis, which sums up my thoughts on the issue:

“It is imperative for ergonomics applications to demonstrate tangible results and justify an organisation’s investment. Initial ergonomics interventions should consider the ‘low

hanging fruit’ by addressing obvious and easily fixed design deficiencies to display short term results, and ultimately gain credibility with management and other stakeholders. This result-oriented approach builds relationships and trust that can be leveraged into longer term, more intensive ergonomics applications.” *NA*

### Further reading

Mallam, S., Lundh, M., MacKinnon, S.N., ‘Integrating Human Factors & Ergonomics

in large-scale engineering projects: Investigating a practical approach for ship design’, *International Journal of Industrial Ergonomics*, Vol 50, 2015

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Mallam, S., Lundh, M., MacKinnon, S.N., ‘Integrating Participatory Practices in Design and Construction’, *Ergonomics in Design*, Vol 25, Issue 2, 2017

# Design for cruise-building in all its varieties

YSA Design takes a flexible approach to capitalise on the cruise shipbuilding market's hunger for fresh ideas, combining an understanding of audiences' characteristics with playful exterior and interior design

It is an exciting period for those designing new cruise ships, as owners aim to meet passenger desires more precisely in mature markets, while the burgeoning Chinese and expedition cruise markets create opportunities for fresh ideas.

Exterior and interior architect YSA Design is strongly engaged in all three of these newbuilding opportunities. Following a company rebranding that builds upon the reputation earned in over 30 years as Petter Yran & Bjørn Storbraaten, the new management team has invested in 3D modelling tools and hired additional staff to ensure that it is prepared to meet the challenges of a fast-changing new ship design sector.

The outcome of matching design experience with fresh ideas can be seen in the company's participation in projects for MSC Cruises, who sought their experience in envisioning spaces that keep children of all ages happy at sea.

"We develop kids' areas based on inclusive design principles, rather than segmentation, and it's an approach that is being sought out as cruising demographics are changing," says Anne Mari Gullikstad, Chief Executive, YSA Design.

The Norwegian company secured a significant body of work on board *MSC Seaside*, the 160,000-tonnes MSC Cruises flagship newbuilding which is the first of a pair set to be homeported in Miami, and which contains the largest ratio of outside spaces of any cruise ship at sea.

The ship's strong emphasis on family was a focus at its naming ceremony in Miami on December 21, 2017. YSA Design undertook a complete project to incorporate Lego facilities onboard, with separate spaces for 'Mini' (3-6 years) and 'Juniors' (7-11 years) clubs.

"This was our first time with Lego and their first time with MSC Cruises. We collaborated closely to ensure concept designs and colour schemes fitted with their furnishings, working with Lego at its headquarters in



YSA Design's collaboration with Lego yielded colourful, interactive play areas

Denmark and at the [Fincantieri] yard in Montefalcone," says Gullikstad.

The success of the project is demonstrated by the award of follow up work for YSA Design to devise Lego facilities aboard the first of four MSC Cruises Lirica-class ships being lengthened at Fincantieri, and further work on the remaining ship renewal projects.

YSA Design's wider expertise has also been called upon on *MSC Seaside* to devise zones that please distinct age groups within integrated spaces that offer seamless flow-through. For example, the concept for the zones connecting the ship's Aqua Park and kids' areas was conceived and developed by YSA Design. "It is a very nice vertical space, including an outside area and an enclosed area that's six decks high," says Gullikstad. "There are bridges, adventure trails, four slides, two ziplines and stairs up to a basketball court that creates a very busy, high energy area used by all age groups."

The ziplines mentioned are the longest at sea – a pair of 130m length wires which descend from Deck 20 to Deck 18. "That is something new and has partly been inspired by Norwegian tastes here at YSA Design for the thrill of the ski jump, but it was an Italian company with experience of working in the Alps found by the MSC project manager that turned the idea into reality."

Gullikstad adds that the company also devised the solution for the ship's basketball court to be located within the MSC Cruises wrapround funnel shield, and decorative rings aft of the funnel that draw the eye from a distance to a pleasing perspective of on-deck activities. The company's involvement in the newbuild also took in interior designs of five 40-seater upscale pay restaurants on Deck 16, connected by a common welcome area.

For a second, undisclosed owner, the seeds are being sown for YSA Design to offer its expertise to newbuilding projects in China, Gullikstad adds. The company has already been part of a radical main deck conversion for a European-built ship to meet Asian cruising tastes at a Chinese yard, and the same owner is following up with a European build conceived for Chinese cruisers.

"It's an exciting prospect as a market and our experience and research has already given us insights into the challenges involved in designing for newbuildings for the Chinese market, ranging from bolder colours to distinctive dining and shopping tastes, and different uses for public spaces," Gullikstad comments. She suggests that Chinese cruisers have less

thirst for bars serving alcohol, for example, so the creativity employed to deliver different bar-room 'vibes' would be better harnessed designing areas for karaoke, or semi-private areas for gaming and socialising, as well as public casinos.

Fewer bars also means lower demand for pantry-style catering, so Gullikstad advises that food and beverage operations need to be set up differently, with a greater requirement for the choice and speed of service offered by buffet-type restaurants, and for more variety in specialty restaurants that provide high quality food and flexibility, as well as live entertainment. As a result, designers must consider consequences that include table sizes and seating arrangements, passenger flows and turnaround times. A refocusing of retail expectations is also required for Chinese tastes; while familiar luxury brands play a major role, there is also desire for a wider range of retail outlets.

Closer to home, but also fast-moving, is the developing market for newbuild expedition ships, where YSA Design's neighbouring yards in Norway have made concerted efforts to attract orders as oil prices have led their traditional offshore customers to close the books on new construction.

For instance, as many as 20 projects to build smaller luxury cruise ships capable of operating in polar expeditions are either currently underway or in the pipeline, and many of the firm contracts have been secured by Norwegian yard groups.



Chinese cruisers respond positively to red, which is associated with good luck and happiness

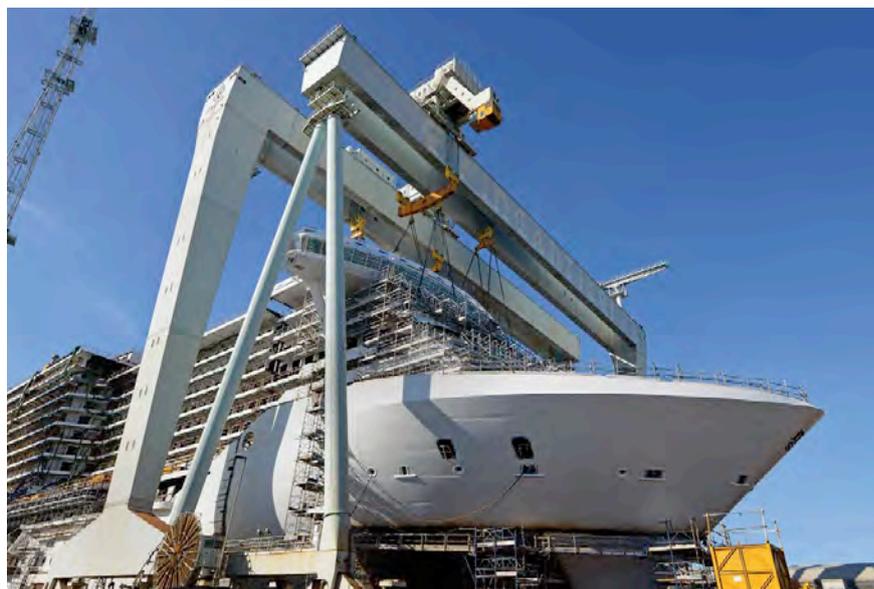
These ships are special in type from the outset given that many are being built to Polar Code 6 for reasons of safety, and some feature innovative propulsion, but the small number of passengers (capacities are mostly between 150-250) mean that they also need to be distinctive by brand. If spectacular surroundings are the draw, use of space onboard and innovative interior design can provide the individuality that brings repeat business.

Small and rugged, expedition ships need to feature all-outside facing cabins and punch above their weight in terms of luxury; guests also expect to enjoy

a panoramic view during their dining, relaxation and fitness experiences.

Gullikstad says that YSA Design has worked behind the scenes to support several Norwegian yards as they have developed the General Arrangement drawings to convert a business opportunity into firm contracts.

"It has been a slightly unusual scenario, but it is fair to say that we have been involved in their campaigns and the yards have been our customers rather than the owners; this has deepened our knowledge in this niche market, putting us in a good position to bid in the months ahead." **NA**



MSC Seaside was built at Fincantieri's Montefalcone yard

# Japanese full-scale propeller performance study aims to clarify scaling effect

Using cutting-edge multi-layered Doppler sonar equipment developed by Furuno, a Japanese research team led by NYK and JMU have been able to measure a full-scale propeller flow field directly, a technique that they believe paves the way for substantial efficiency improvements

In order to minimise ships' fuel consumption, great efforts have been made all over the world to design and develop hull, propeller and energy saving devices and to improve operational efficiency in service. Whether before or after a delivery of a ship, a grasp of ship performance in full scale by designers, owners and operators is essential to attain such efficiency. Accurate performance monitoring in service yields efficient operation [1] as well as adequate judgement of maintenance timing for hull and propeller cleaning [2].

Information on ship performance in full scale is particularly crucial for a designer. Ship design is usually based on model tests and/or theoretical calculations. One of the difficulties in ship design is a scaling of the flow field from model to ship. Although an optimal design in model scale can be accomplished, full-scale optimisation cannot be evidenced due to the lack of the correlation data concerning Reynold's scaling effect. Direct calculation in full scale is becoming available with the development of computational fluid dynamics (CFD) (e.g.[3]), but optimisation in full scale purely based on CFD is still questionable because there is little reliable data for verification and validation. To substantially improve ship performance, we need to collect full-scale data in order to deepen our understanding of the scaling effect.

With the above background, Nippon Yusen Kaisha (NYK), MTI Co, Ltd. (MTI), and Japan Marine United Corporation (JMU) have started a joint research project on full-scale measurement for 14,000 TEU container ships. Propeller performance is a focus in particular because it greatly impacts whole ship performance. The

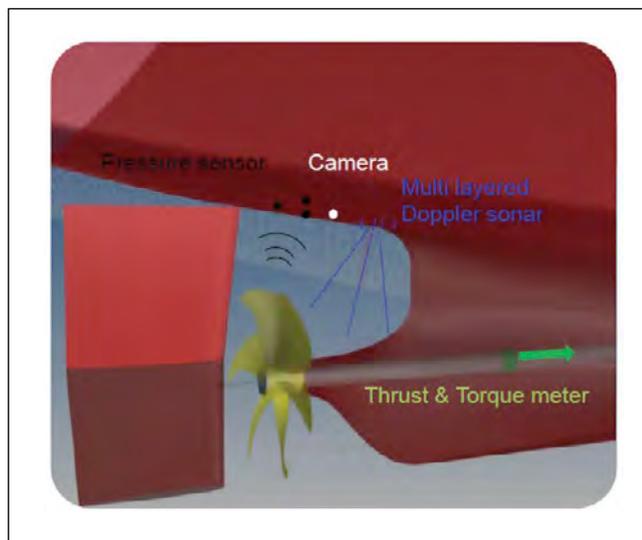


Fig.1: Illustration of the measurement system



Fig.2: Picture of a NYK 14,000 TEU series container ship

purpose of this project is to grasp the precise working condition of the propeller during voyages and feed this data back to, and optimise, the design.

In addition to the usual performance monitoring (speed, power etc.), the project also involves extensive investigation into factors such as thrust measurement and

cavitation observation. Fig.1 shows an illustration of the measurement system.

The most challenging of these investigations is a direct measurement of the full-scale flow field around the propeller. Inflow velocity to the propeller greatly influences hull and propeller performance and is thus very important information for

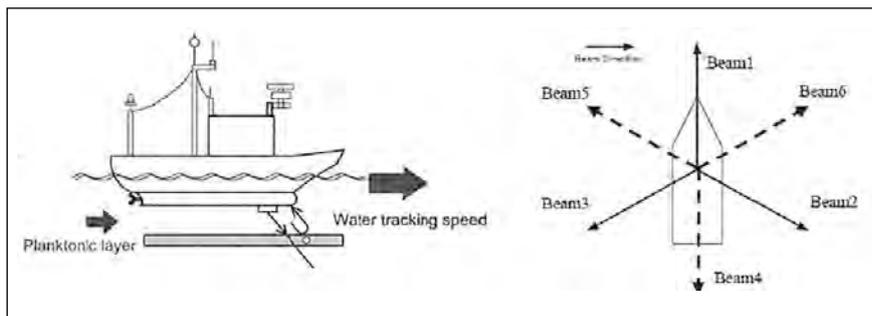


Fig.3: Illustration of principle of Doppler sonar and ultrasonic beams transmitted from the transducer (6)

a ship designer. However, measurements of flow velocity (e.g. by LDV [4] or PIV [5]) are confined by their complexity and the financial cost of the measurement system.

To resolve this situation, JMU, NYK, and MTI have developed Multi-Layered Doppler Sonar (MLDS), created in collaboration with Furuno Electric Co. Ltd. (Furuno). MLDS is an acoustic Doppler sonar capable of measuring relative water velocity at multiple arbitrary depths along ultra-sonic beams. NYK, MTI and Furuno have already applied this MLDS to a pure car carrier in service and reported that the measured flow velocity distribution at stem bottom agreed well with the CFD calculation [6]. Flow measurement at the stern, however, was thought to be more difficult compared with that at the stem because of the following reasons:

- The flow field at the stern lay in a complicated thick boundary layer.

- The sonar should be located on the hull surface near the water surface where rich, bubbly flow might occur.
- The effect of obstacles like the hull and propeller on the ultra-sonic beams.
- The propeller emits acoustic noise.

The project was therefore divided into two stages. For the first stage, an MLDS was installed at the stern to investigate whether it could measure the velocity within reasonable accuracy, overcoming possible error causes. Furthermore, propeller cavitation, which is influenced strongly by the inflow velocity distribution to the propeller disk, was observed using a borescope. If the capability of MLDS during the first stage could be confirmed this would justify a second stage of more advanced measurement. In this report, results of full-scale measurement at the first stage are presented.



## 14k container ship

The measurement was performed in August 2017 on a 364m loa, 14,000 TEU container ship built by JMU and operated by NYK on a Far East – Europe route, while it was underway from the Suez Canal to Rotterdam. During the measurement, the weather was generally good. Absolute wind velocity changed up to 13m/s and significant wave height changed up to 2.5m.

## MLDS

MLDS was developed by Furuno based on their Doppler sonar product Model:DS-60 [7] but with a revised signal processing algorithm. Three ultrasonic beams are transmitted from the transducer and the flow velocity in the beam direction is measured using the acoustic Doppler effect. Fig. 3 shows an illustration of the principle of Doppler sonar and direction of the transmitted beams [6]. MLDS can measure flow velocities simultaneously at the depth of nine points designated arbitrarily. The beam direction can change by 180 degrees so that you can measure the flow velocity in six directions at every 60 degrees. Because MLDS has the same hardware as DS-60 which are widely used as speed and distance measurement equipment (SDME), it is easier to install and less expensive compared to other measurement systems, such as LDV or PIV. In fact, a DS-60 was installed to the subject vessel as a SDME at the stem. Fig. 4 shows the MLDS equipped on the subject vessel at the stern. The transducer was attached to the bottom at the port side and measured data was transferred to the PC via the transceiver in the steering gear room. Neither the distributor nor the indicator, which are standard components of the DS-60, were installed.

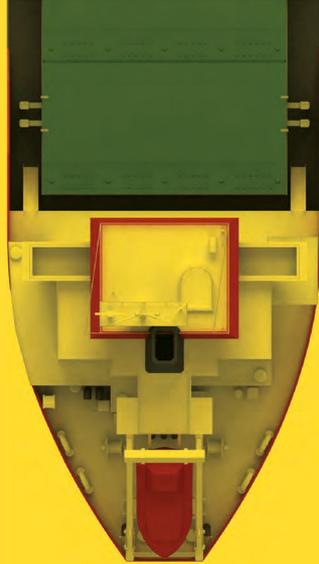
## Flow field measurement

Fig. 5 (overleaf) shows the velocity distribution in the beam direction against the distance from the transducer to measured points. The velocity is normalised by the ship speed measured by the DS-60 installed at the stem. Each mark represents a

Fig.4: MLDS equipped (left: gate valve for the transducer of the MLDS at the bottom; right: the transceiver of the MLDS and PC for analysis in the steering gear room)

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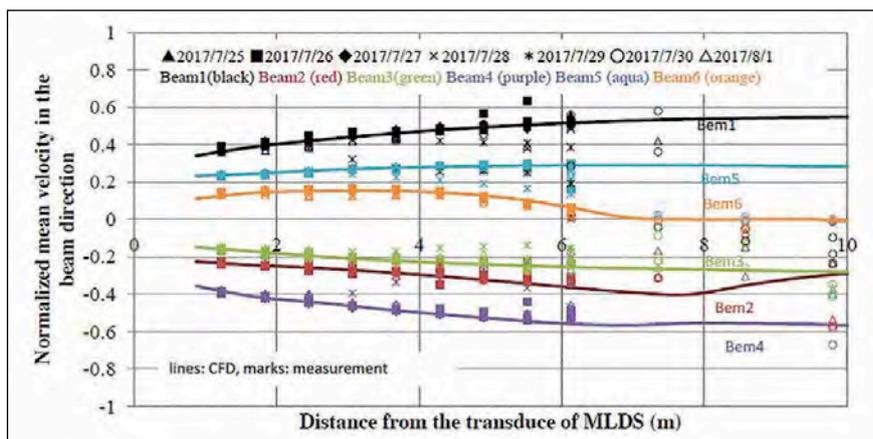


Fig.5: Comparison between measurement and calculation on normalised mean velocity in the beam direction (lines: CFD; marks: measurement)

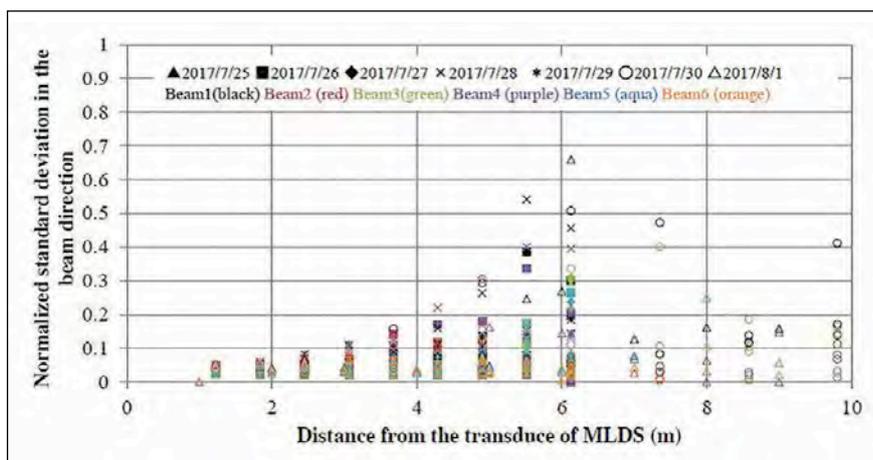


Fig.6: Normalised standard deviation of velocity in the beam direction

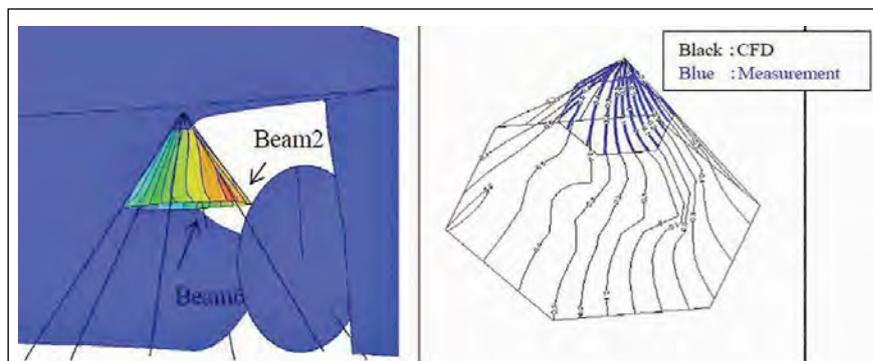


Fig.7: Contour of flow velocity in the beam direction (black: CFD; blue: measurement)

mean velocity which was measured several times a day for about 10 minutes duration when not maneuvering. The numbering of the beam in the figure corresponds to that in Fig. 3. The estimated velocity by calculation is also shown as the lines in Fig.5. The calculation was done using the SURF code for CFD [8], which is an incompressible Reynolds averaged Navier-Stokes solver, developed by Japan's

National Maritime Research Institute. Further, the standard deviation of measured velocity normalised by the ship speed is shown in Fig. 6. The following findings can be derived:

- In the range of within about 6m from the transducer, the measured mean velocity in the beam direction fairly agrees with the estimation by the CFD. When the distribution was drawn as a contour on a

surface of hexagonal pyramid composed of the six beams as shown in Fig. 7, we can see more easily that the measurement agreed well with the CFD calculation.

- Generally good reproducibility was seen in the range of within about 6m from the transducer. Only the data measured on 29 July (asterisk marks, Fig. 6) were scattered, but the reason for the discrepancy is not obvious. Since the sea condition was not much different from the other days, water quality might be what is affecting the measurement result. Further investigation of the reason is required.
- The standard deviations of velocity in the beam direction were reasonable within 5% of the ship speed in the range of about 3m from the transducer, while they increased gradually as the distance from the transducer got larger.
- In the area from about 6m away from the transducer, beam 2 hit the propeller and beam 6 hit the hull as shown in Fig. 7, which influenced the measured velocity in the direction of the other beams. Accordingly, the standard deviation in the direction of all other beams got larger by mutual interaction and reasonable measurement became impossible.

In conclusion, it was determined that the MLDS exceeded expectations although some modification is necessary. Work is now underway to study countermeasures against the problems of the beam hitting the propeller and the hull affecting the measurement on the other beams. During the second stage it is planned to revise the MLDS and enlarge the range of the measurement.

### Cavitation observation

Excessive cavitation reduces efficiency and causes harmful phenomena such as hull vibration and/or erosion on the propeller and rudder, making it the most important issue in propeller design. One of the reasons why flow field measurement is so important is that cavitation behaviour is influenced strongly by the flow field in which the propeller works, i.e. the wake field [9]. Cavitation observations were made on the same voyage as the flow field measurement and investigation undertaken into how the cavitation pattern differed from that in a model test.

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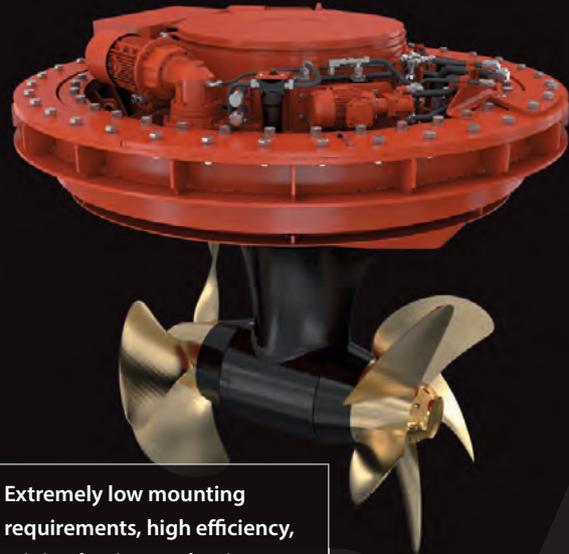
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The model test was conducted in the JMU cavitation tunnel with a square test section of 0.6m x 0.6m. The wake field was generated by a wire mesh screen placed upstream of the propeller. The wake distribution was simulated by extrapolating the measured model scale wake with the Sasajima-Tanaka method [10], a well-known wake scaling method. The cavitation was observed using a high speed camera. The full-scale observation was taken with a borescope and two kinds of camera: a high speed camera and an ultra-high sensitivity camera.

Thanks to the good water quality of the Mediterranean Sea, we could capture very clear pictures by both cameras. Fig. 8 and Fig. 9 show a comparison of observed cavitation patterns between model and full scale. All the pictures in the figures were taken by a high speed camera. The cavitation pattern in full scale was widely similar to that in model scale. As we say that 0° is the position when a key blade of the propeller is at the top, sheet cavitation appeared at around the 5° position, developed into maximum extent at around the 35° position and disappeared at around the 70° position.

The largest sheet cavitation covered over the non-dimensional propeller radius of  $r/R=0.85$ . This implied that the prediction by the Sasajima-Tanaka Method was a good approximation of the full-scale wake field. However, the extent of sheet cavitation in full scale was a little bit larger than that observed in the model test when the blade going downward and passing at around the 55° position as shown in Fig. 9. Since cavitation occurs more in the region where the inflow velocity into the blade is slower, it was presumed that the flow velocity at around the 55° position was slower than the assumed flow in the model test. This kind of observation would greatly contribute to the further development of the present wake scaling method.

#### Future work

We have confirmed the capability of the MLDS for the measurement of a full-scale flow field at the first stage of the project. Further, the cavitation behaviour observed gave us hints to consider the flow field in full scale. It is a big step toward further sophisticated propeller design.

Following these fruitful results, the second stage in spring will carry out more advanced measurement on a sister vessel, during which a wider range of flow field measurements with multiple MLDSs, direct measurement of propeller thrust, pressure fluctuation, and cavitation observation will be executed. *NA*

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Fig.8: Comparison of cavitation pattern at the 35° position in model test (left) and in full scale (right)

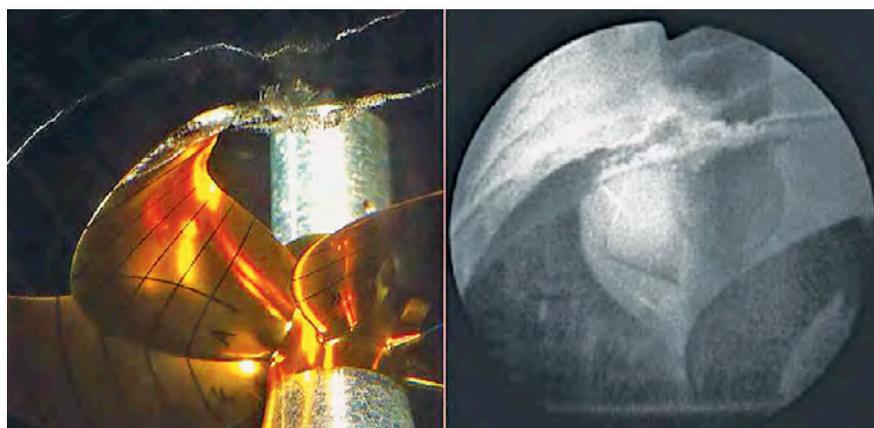


Fig.9: Comparison of cavitation pattern at the 55° position in model test (left) and in full scale (right)

# Great Intelligence stakes a claim for Chinese smart ships

As per its name, this trailblazing SDARI-designed vessel features an advanced array of cyber systems, incorporating AI technology and big data to optimise whole-ship performance

The January edition of *The Naval Architect* reported the launch of the much-anticipated vessel *Great Intelligence* (*Da Zhi*), heralded as China's first significant 'smart ship,' at Marintec China. A re-design of fuel-efficient sister ship *Green Dolphin*, the 38,800dwt bulk carrier is a collaboration between the Shanghai Merchant Ship Design and Research Institute (SDARI), the System Engineering Research Institute (SERI - part of the China State Shipbuilding Corporation), and the classification societies Lloyd's Register (LR) and China Class Society (CCS). First announced in 2015 and taking three years to complete, *Great Intelligence* was conceived from the beginning as a 'smart' or 'digital' ship, incorporating an array of systems across the vessel to improve safety, economy, and fuel efficiency, and lessen environmental impact. In recognition of the centrality of this technology to *Great Intelligence*, the vessel attained Lloyd's Register's descriptive notes for a 'cyber-enabled ship,' making it the first Chinese vessel to do so and one of a small number worldwide.



*Great Intelligence's* smart systems will allow the bulk carrier to optimise its economic and environmental performance on a continuous basis

## An intelligent vessel

*Great Intelligence* is perhaps the most significant affirmation yet of the growing awareness in the maritime industry of the benefits of 'big data': collecting, analysing, and acting upon mass amounts of data, in real time, in order to optimise vessel performance and operating procedures. In effect, all of *Great Intelligence's* smart systems draw on the big data principle, working to optimise a particular area of ship operation from routing to emissions. When combined, these smart systems generate a vessel-wide holistic network that allows the vessel to constantly evolve and improve by recognising and cancelling out performance inefficiencies wherever they occur. By collecting and acting on data in real time, too, *Great Intelligence* can respond to situations as they arise, achieving immediate results. Moreover, by employing the Artificial Intelligence (AI) software built into its systems, which relies on algorithms, the vessel can 'learn' from historical data and forecast unexpected future situations, generating solutions before they become an issue.

Two key smart systems define *Great Intelligence*: the Ship Operation and Management System (SOMS) and the

Intelligent Navigation System (INS). The former is split into three constituent parts: Health Management, Energy Efficiency Management, and the Intelligent Integration Platform. The first, Health Management, monitors the parameters within which different pieces of equipment are operating, in order to support crew decisions relating to equipment adjustment or operation. The second, Energy Efficiency Management, monitors energy consumption, fuel levels and emissions, and voyage parameters, to optimise energy usage throughout each journey. The Intelligent Integration Platform, the third aspect of SOMS, works to tie together the system, by combining the data collected by Health Management and Energy Efficiency Management and analysing it to present crew with the information they need to make operational decisions that impact the vessel as a whole confidently. As well as collecting data, the SOMS also allows for streamlined data management, a task that can otherwise be a headache for operators.

Complementing the Ship Operation and Management System is the Intelligent Navigation System (INS). Designed to 'augment' rather than 'replace or impact'

### TECHNICAL PARTICULARS

#### *Great Intelligence*

Length (OA).....	179.95m
Breadth.....	32.00m
Depth.....	15.00m
Draught.....	10.50m
Deadweight.....	38797dwt
Cargo capacity.....	50906m <sup>3</sup>
Main Engine.....	WinGD W5X52
Propeller(s).....	6.4m Dia. X 3
Service Speed Average.....	13.9knots
Complement.....	26 persons
Kind of Vessel.....	Bulk carrier

the ship's regular navigation and safety systems, the INS collects data from both ship and shore to suggest potential adjustments to the vessel's baseline route, with an eye towards optimising it in a variety of ways; for instance, the INS might point out a shorter route, leading to lower fuel consumption and journey time, or calculate a route that avoids a sudden storm or rough seas. By collecting this data in real time, on a constant basis, the INS automates the time-consuming process of manually contacting service stations to obtain route and meteorological information, lessening the delay between gaining and acting on new information.

Commenting on the attributes of *Great Intelligence*, LR Marine and Offshore Director Nick Brown stated: "It is a true landmark for all parties involved. We are very proud to be helping our clients build more autonomous ships that are safer, more efficient and energy saving." While *Great Intelligence* features technology that allows for a certain level of autonomy, as Brown notes, it is important to recognise that it is not fully autonomous; its smart systems cannot make decisions separately from crew, but rather act to advise and aid decision-making. As such, *Great Intelligence* represents a step forward in autonomous ship technology, but is at a distance yet from the promise hinted at by Rolls-Royce and others of fully autonomous vessels in the near future.

### A cyber-enabled ship

Part of *Great Intelligence*'s significance comes from Lloyd's Register's presentation of cyber-enabled ship descriptive notes to the vessel – Cyber AL2 Safe, Cyber AL2 Maintain, and Cyber AL2 Perform – at Marintec China 2017. The classification society was the first to develop notation in the area of smart / cyber-enabled ships, releasing their initial guidance document, 'Deploying Information and Communications Technology in Shipping – Lloyd's Register's Approach to Assurance,' in February 2016. This guidance defines the cyber systems that underpin a cyber-enabled ship, and their safe application: "Cyber systems transform a ship into a total system of interlinked systems ('a system of systems'). While cyber systems are not exact substitutes for

traditional electro-mechanical systems on board ships and their operators, they provide opportunities to combine these traditional components with more complex behaviour. When designed properly, the use of ICT can increase efficiency and safety through improved monitoring and communication, and greater situational awareness on the bridge, in the engine room and in other operational areas." The document was followed in July 2016 by the release of the ShipRight procedure, which explains precisely how LR intended to apply their guidance, detailing "LR's framework for accepting cyber technology at varying levels of autonomy."

As cyber-enabled shipping represented uncharted waters for Lloyd's Register, the classification society took pains to thoroughly consult the industry whilst creating its guidance. As Luis Benito, Marine & Offshore Innovation and Strategy Director, explains: "LR did indeed work with designers, builders, technology providers, flag administrations, ships owners and operators and smart systems designers in creating our procedures."

*Great Intelligence*'s achievement of CES notes was expected, given that LR "was involved at a very early stage of this project"; in fact, the newbuilding actively contributed to the early development of LR's guidance. Benito explained the timeline of the project: "In 2014 we signed a JDP agreement with CSSC SERI to support them in the development of the SOMS system (the cyber enabled system installed on board *Great Intelligence*). At the following step, where CSSC began to discuss the possibility of building a real vessel equipped with the smart system, SDARI became involved and we helped SERI and SDARI to develop the ship specification. At that time we had written our cyber-enabled ships guidance and we started to apply this to this project."

In particular, Benito noted that *Great Intelligence* aided LR in creating their ShipRight procedure, which signalled a move from theory to the practical application of cyber-enabled shipping notation: "The ShipRight Procedure was partly created to include direct feedback from on-going projects, and the *Great Intelligence* project was one of these."

### Future-proof classification

Central to Lloyd's Register's guidance and assessment in the area of cyber-enabled shipping is the importance of taking what they call a "non-prescriptive approach," as the rapid advancement of cyber technologies means new systems are arriving on the market and existing systems are being improved faster than guidance can be updated. Commenting on how this works in practice, Benito explained: "The approach recognises a number of areas that need to be carefully considered in the system design, such as overall system architecture, human-system interface, system integration, communications network, and security, and then applies LR's Risk-Based Design methodology to determine the scope of system under assessment, challenge the design, and confirm appropriate mitigations to the risks identified are implemented."

By identifying 'areas' rather than specific systems that require assessment, Lloyd's Register appears to be exploring a more flexible, case-by-case approach to classification, which is arguably more future-proof than a stricter, prescriptive process. However, September 2017 saw LR release the first type approval procedure for cyber enabled components, which may offer a boon for owners and designers of smart ships who are looking to fast-track the classification process by selecting type-approved products that meet LR's requirements from the beginning, rather than hoping that their unique cyber system is up to standard.

As one of the pioneer cyber-enabled ship projects, and the first Chinese vessel to receive LR's CES descriptive notes, *Great Intelligence* is sure to be seen as a consequential vessel, staking a claim for SDARI and CSSC as institutions at the forefront of ship design, and for Lloyd's Register as the leader in smart ship classification. As the vessel settles in to its working life, transporting coal and salt between Australia, China and Southeast Asia for Sinotrans Shipping, the efficiency and economy offered by its cyber systems will soon become apparent; if the theory of smart ships is validated in practice by vessels such as *Great Intelligence*, we are sure to see further integration of cyber systems in the coming years. **NA**

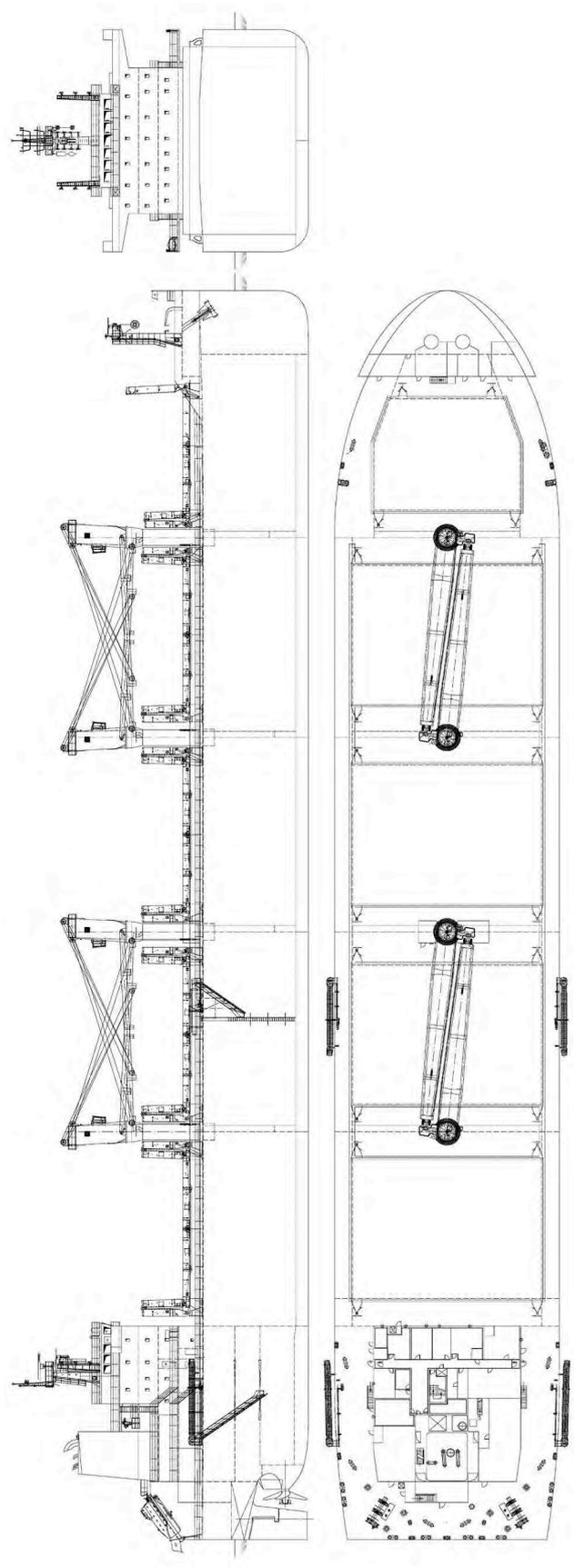
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# Best practices for wave flow simulations

Realistic wave propagation with numerical modelling is one of the persistent challenges of CFD. How can ocean engineers accurately reproduce the complex conditions found at sea?

Professor Milovan Perić, former VP of Technology at CD-adapco (now part of Siemens PLM Software) and latterly an independent consultant, has spent more than 30 years at the leading edge of research into finite-volume based CFD analysis. Perić was one of the major contributors to the development of Computational Continuum Mechanics technology, which evolved into today's industry standard STAR-CCM+ platform.



Milovan Perić

STAR-CCM+ is a sophisticated tool but there are numerous issues affecting the predicted propagation of waves using numerical methods like those implemented in the platform. At a presentation at last year's STAR Global Conference in Berlin, and subsequently in conversation with *The Naval Architect*, Perić gave an outline of some of the problems encountered and techniques by which the problems can be overcome. Some of the major problems engineers may encounter when simulating wave propagation are:

- A wave's amplitude reduces along the propagation distance so that its height is not correct when it reaches the object (e.g. vessel).

- The wave period may also change during propagation.
- Disturbances on the free surface may appear, meaning that the wave is not smooth.
- Perhaps one of the largest problems is reflections occurring at the solution domain boundaries.

For the purposes of illustration, Perić presented the results of two waves created

using STAR-CCM+: a model-scale wave of 0.06m height (Wave A) and another of 4m height (Wave B), both configured at the inlet with Stokes fifth order wave theory (See Table 1).

## Factors affecting wave propagation

A critical factor in wave propagation is the temporal discretisation. Perić says the first order implicit Euler method (for solving ordinary differential equations) is too dissipative to yield satisfactory results as it severely dampens the wave amplitude when it propagates over multiple wavelengths. Using the second order quadratic fully implicit scheme can provide a time-accurate simulation of wave propagation, but it imposes a limit on how far the interface may move within a time step. If the time step is so large that the wave moves more than half a cell per step, then the quadratic interpolation can create an 'over-shoot' or 'undershoot' effect (i.e., the water volume fraction – which should be between zero and one – may get out of bounds). A comparison of solutions obtained using the first order Euler and second order quadratic scheme can be seen on Figure 1 (the wave amplitudes have been magnified for illustration purposes).

Table 1

Wave A	Wave B
Wave height: $H = 0.06$ m	Wave height: $H = 4$ m
Wavelength: $\lambda = 0.8$ m; Wave steepness: $H/\lambda = 0.075$	Wavelength: $\lambda = 47.154$ m; Wave steepness: $H/\lambda \approx 0.085$
Water depth: $d = 5$ m; Solution domain length: 6 m	Wave period: 5.304 s
Wave period: $T = 0.7$ s	Water depth: 77.2 m
$\Delta x = 0.01$ m (80 cells per wavelength) or 0.005 m (160 cells per wavelength)	Solution domain length: 188.6188 m (4 wavelengths)
$\Delta z = 0.005$ m (12 cells per wave height) or 0.0025 m (24 cells per wave height)	$\Delta x = 0.5$ m (94 cells per wavelength)
Aspect ratio: $\Delta x/\Delta z = 2$ (for coarse grid, also aspect ratios 1 and 4 were tested)	$\Delta z = 0.25$ m (16 cells per wave height)
Time step: 0.003 s or 0.0015 s (233 or 466 time steps per wave period)	Aspect ratio: $\Delta x/\Delta z = 2$
Under-relaxation parameters: 0.8 for velocities, 0.4 for pressure, 0.8 for volume fraction	Time step: 0.01 s (530 time steps per wave period)
Outer iterations per time step: 10 (not optimized for efficiency, rather conservative)	Turbulent flow
Inviscid, laminar or turbulent flow	Second-order time discretization
Second-order time discretization	Second-order space discretization
Second-order space discretization	Gradients: Hybrid Gauss-LSQ
Gradients: Hybrid Gauss-LSQ	Initial conditions: Stokes 5 <sup>th</sup> -order wave theory
Initial conditions: Stokes 5 <sup>th</sup> -order wave theory	Boundary conditions: Stokes 5 <sup>th</sup> -order wave at inlet and outlet with forcing over one wavelength
Boundary conditions: Stokes 5 <sup>th</sup> -order wave at inlet, damping at outlet over $2\lambda$	

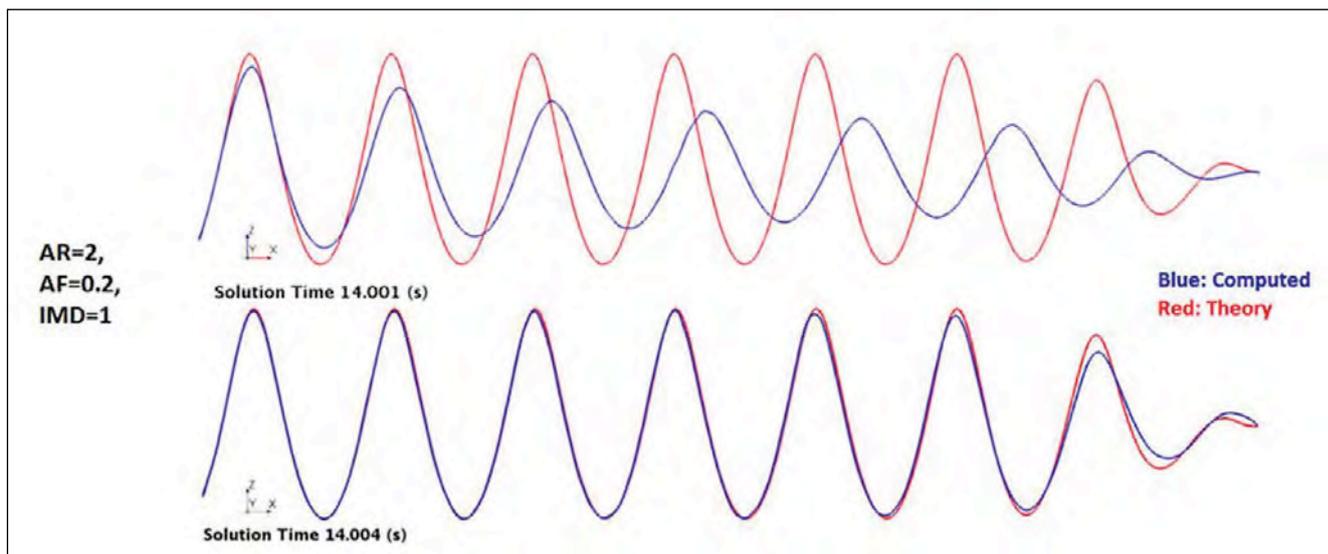


Figure 1: Using the implicit Euler method the computed wave quickly deviates from the theoretical value, while the second-order method preserves much better both the amplitude and the period of the wave

To achieve a satisfactory solution, Perić recommends that the free surface should not move more than 40% of the cell size, with 50% being the absolute limit (a Courant number of 0.4 or 0.5). He speculates that in the future it may be possible to devise a special treatment for cells where the criteria is exceeded (like small cells in near-wall prism layers), so that it's still possible to use larger time steps that are adequate for wave propagation away from bodies but with the ability to use first order discretisation

in zones where cells are much smaller for other reasons (e.g. resolution of boundary layer at a wall).

### Grid effects

The choice of grid resolution - the number of cells per wavelength and wave height - is another important factor that affects the solution considerably. A coarser grid with fewer cells will reduce accuracy, but even with a grid of 12 cells per wave height by 80 cells per wavelength it is still possible to achieve a good result with only slight loss

in wave amplitude, but with a considerable saving in computing time.

However, the aspect ratio (AR) of the grid (the ratio of the longest to the shortest edge) has a surprisingly high influence on the solution. Perić recommends using an aspect ratio of 2 for propagating steeper waves and 4 for those of a lower amplitude (see Figure 2). He explains: "I found out by trial and error that if you have a steep wave then you should have cells which are twice as long as high. It's not good to make them too quadratic because you may get

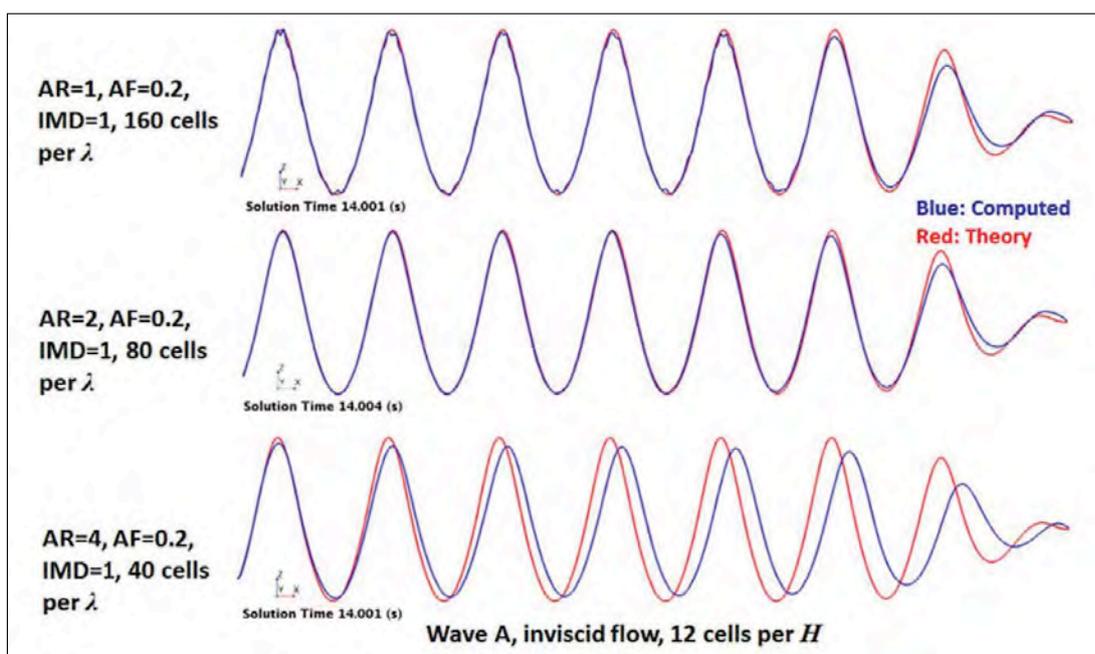


Figure 2: For effective results, the Aspect Ratio (AR) should be adjusted according to the wave steepness: quadratic cells may lead to disturbances at free surface (upper) while too flat cells may affect the wave height and period (lower).

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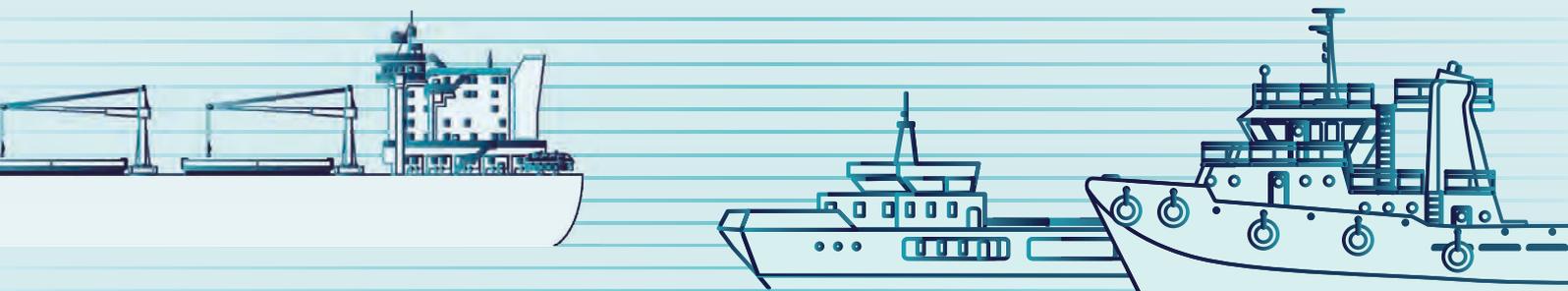
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some disturbances at the free surface. These are things we can improve with refinement of the high resolution interface capturing scheme (HRIC), so that it doesn't matter if your cells are quadratic or more stretched. A certain number of cells per wavelength or wave height will always be necessary to achieve an acceptable accuracy, but the results should not get worse if you take in any direction more cells than necessary."

The HRIC scheme also includes a parameter called the Angle Factor (AF) which has default value of 0.05, but Perić's tests have revealed that higher values of 0.15 to 0.2 actually achieve better results. The effect of Interface Momentum Dissipation (IMD) parameter, a tool originally designed to improve simulations when surface tension effects dominate, can also be significant. In the case of the model-scale Wave A it was found that setting the IMD-parameter to 1 gave the best results, however the larger amplitude Wave B was not much affected by this parameter.

### Effects of turbulence model

The Navier-Stokes equations, which describe the fluid flow, are at the heart of finite volume modelling and make it possible to deduce the pressure and velocity distribution in a wave. In a flow without any obstacles in the water, the fifth order Stokes theory is the optimum setting for regular long-crested waves. However, in the presence of solid walls boundary layers develop and if the velocity is high enough, then perturbations are introduced and the fluid's flow becomes irregular; in other words, turbulence occurs.

Perić explains: "This is something [Osborne] Reynolds explored. He was the first to demonstrate with his experiments how a parallel streamline can suddenly become disturbed when the velocity (i.e. Reynolds Number) exceeds a certain limit. Reynolds demonstrated this for pipes but it's true of any boundary layer – after a certain length the flow along a wall becomes turbulent."

"If you have a body such as a ship then you need a turbulence model, but we have to make sure this turbulence model doesn't screw up the wave coming against the ship, which should propagate naturally."

Theoretically, Navier-Stokes equations themselves describe turbulent flow

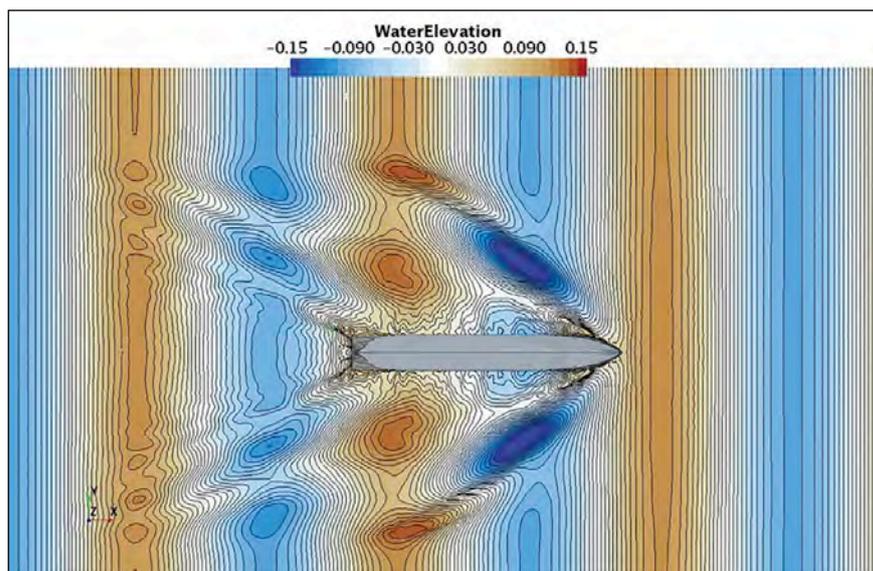


Figure 3 - Container ship in Stokes waves: Simulation of ship-wave interaction by applying forcing towards Stokes theory over half a wavelength along all boundaries, thus preventing wave reflections from boundaries.

accurately, but to simulate such seemingly random fluid behaviour - from tiny vortices of a few millimetres to waves over 100 metres - by solving directly the Navier-Stokes equations is impractical: the required computing effort grows exponentially with increasing Reynolds number (proportional to  $Re^3$ ). Such direct simulations of turbulence cannot be afforded even at the model scale, so the Reynolds-averaged Navier-Stokes equations (RANS equations) with turbulence models have to be used. Turbulence models mimic the effects of turbulence on the mean flow by introducing turbulent viscosity, which is not a fluid property but depends on the flow and is determined by solving additional equations.

The problem is that this turbulence viscosity may negatively affect the wave propagation. This is usually not noticed in simulations that span only a few wave periods, but if the simulation is supposed to last for many wave periods, turbulent viscosity may grow too high and thus damp the wave amplitude. Some turbulence models are more prone to negatively affecting the wave propagation than others but Perić explains: "The standard 'low-Re  $k-\epsilon$ ' turbulence model in STAR-CCM+ will prevent excessive growth of turbulent viscosity if turbulent kinetic energy and its dissipation are adequately initialised."

One of the major problems when simulating wave propagation and interaction with floating bodies is the reflection at solution domain boundaries. Especially in longer lasting simulations, wave reflections can spoil the flow in the whole solution domain. Perić says: "A typical approach nowadays is that we try to get the wave approaching the body [e.g. ship] as accurately as possible, undisturbed, and then some distance downstream of the body we don't care about the waves anymore. Typically that requires some damping to flatten the free surface down again. So we want to dampen the waves as if some artificial force was there to prevent motion of the fluid in a vertical direction. Therefore we apply source terms in momentum equations for the vertical velocity component to gradually bring that motion down to zero."

However, when it comes to ships in waves, unless a vessel has a Froude number greater than 1 (something which only applies to so-called 'planing' vessels such as racing or patrol boats - most commercial vessels move in the range of  $Fr$  0.15-0.25) then it will also generate disturbances which travel upstream. This means that damping can only be applied behind the ship; incoming waves should not be affected. Much of the research now being conducted by Siemens, as well as a number of universities, is focused

on finding a way to allow these disturbances to travel away from the body naturally and not reflect back from solution domain boundaries and compromise the solution.

To manage this problem Perić uses a technique he calls “solution forcing”. “What we do is force the Navier-Stokes equation towards a theoretical solution by using appropriate source terms in the momentum equations, which vary smoothly from zero at some distance from boundary to the maximum value at the boundary. If, for example, you’re studying the interaction of a body with a Stokes wave, then we will say that at a sufficient distance away from the body, for example half a ship length, the forcing towards Stokes wave theory starts. In this way the solution gradually transitions from Stokes theory at the boundary towards the solution of the Reynolds-averaged Navier-Stokes equations around the body. The theoretical solution is derived from potential theory, so it doesn’t exactly satisfy the Navier-Stokes equations, but for engineering purposes it’s a very good solution.” Disturbances propagating away from body are thus gradually absorbed without causing reflection problems. Figure 3 shows an example of a simulation of the interaction between a container vessel and a Stokes wave whose wavelength is similar to the ship’s length.

But when it comes to irregular waves, forcing cannot be applied in the same way. In ocean engineering one typically employs the Pierson-Moskowitz or JONSWAP spectra for describing irregular waves, which means superposition of hundreds of sine waves of different lengths and amplitudes with a random phase shift, which build up into an irregular pattern. This is fine for describing the properties of waves entering the specified solution domain but the Navier-Stokes equations will transport the waves differently during computation to the theoretical propagation. This means that forcing can only be applied at the inlet.

Perić has found it is possible to get around this problem by applying different kinds of forcing at different boundaries. One has to allow irregular incoming waves to travel around the body so that any disturbance that’s

### Best practice recommendations for wave propagation with STAR-CCM+

- Use 2nd-order time discretisation, but observe limitations for time step size: base time step size on Courant-number in the free-surface zone only.
- For steep waves ( $H/\lambda > 0.04$ ), use aspect ratio 2 within free-surface zone. For less steep waves, aspect ratio can be 4.
- Use 10 -20 cells per wave height. Cells per wavelength results from chosen aspect ratio.
- Set angle factor in HRIC-scheme to 0.15 – 0.2, in order to reduce wiggles on free surface.
- If needed, activate Interface Momentum Dissipation in Phase Interaction modeling, in order to eliminate wiggles on the free surface.
- If turbulence has to be modelled, use ‘standard low-Re  $k$ - $\epsilon$ ’ turbulence model with all- $y^+$  wall treatment.
- Set initial values for  $k$  and  $\epsilon$  to:  $k = 1e-5$ ,  $\epsilon = 1e-4$  to minimise the growth of turbulent viscosity in the free-surface zone.
- Set the same values for  $k$  and  $\epsilon$  at inlet and pressure boundaries, for the same reason.
- When Stokes 5<sup>th</sup>-order wave is considered, apply forcing at inlet, outlet and side boundaries over a distance corresponding to the vessel/object size, and pressure boundary condition at the top boundary.
- With irregular waves, apply forcing at inlet towards theory, wave damping or forcing vertical velocity comp. to zero at outlet, and forcing of lateral velocity toward zero along the side boundaries.
- Set forcing coefficient to approx.  $20/T$ , where  $T$  is the wave period.

radiated will not reflect against the side boundaries. This is achieved by forcing all velocity components in the zone next to inlet boundary towards the theory; at sides the lateral velocity component is forced towards zero while at the outlet the vertical component is forced towards zero to damp the wave completely.

More detailed study into wave-structure interaction has been conducted at an academic level, including closer investigation into the amplification of Peregrine-type freak waves by Milovan’s son, Robinson Perić, within his Master’s project at the University of Hamburg. Perić Sr. explains: “There has been a lot of theoretical work about the formation of freak waves which can develop for no obvious reason. [Howell] Peregrine was one of the guys who developed the mathematical model for it, but these models are based on the nonlinear Schrödinger equation, which can tell you when wave amplification will or won’t happen but the theory doesn’t completely fit the experimental data.

What my son did was use STAR-CCM+ to simulate the flow by solving the Navier-Stokes equations. You need to compute over many wave periods to get the amplification process but he showed that Navier-Stokes equations do it very well.”

Looking further ahead, Perić anticipates that software such as STAR CCM+ will be further refined and made more intuitive and self-adaptive. “The aim is to make the effects of these numerical parameters less prominent, so users don’t have to take care of things such as aspect ratio, angle factor and wave damping parameters.

“The nice thing with Navier-Stokes equations is we can do everything in full-scale with realistic boundary conditions. Of course, validation is a problem and one should never trust numerical solutions blindly. I hope there will be more full scale CFD workshops such as the one LR has conducted (see May 2017’s *Naval Architect*) because we really should get away from using model scale for anything other than validation purposes.” [NA](#)

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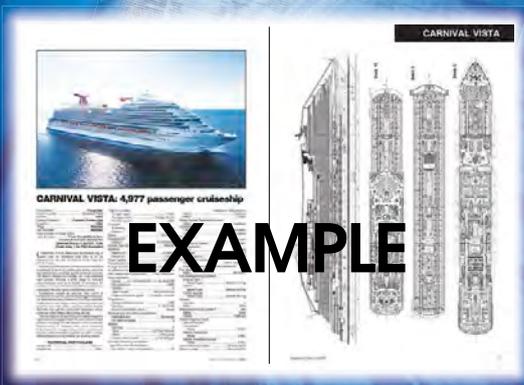


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# New projects put RS at the heart of Arctic shipping

Following technical supervision of the first icebreaking-capable gas carrier launched last year, the Russian classification society is researching further advances in Arctic infrastructure

Nowadays the principal conditions for major offshore projects to be successfully developed in the Arctic are their safety for the region's sensitive ecosystem and economic efficiency. Given its extensive experience of ice class ship classification, it should come as no surprise that the Russian Maritime Register of Shipping (RS) continues to be heavily engaged in developing technical solutions in shipbuilding to reduce shipping's impact on the Arctic environment and enhance operation of the high-latitude oil and gas fields.

RS is actively participating in the construction of multipurpose Arctic ships capable of performing several functions at once. Such technical solutions allow for a reduction in the quantity of operating fleet units without cutting down the range of tasks performed in the oil and gas production area.

Innovations applied under RS technical supervision will also facilitate hydrocarbon transportation in the Arctic seas. For example, when constructing the latest generation of general-purpose Arctic gas carriers, such as the *Christophe de Margerie*, it was possible to effectively combine the functions of a large-capacity cargo ship with an icebreaker's potential. New gas carriers are capable of operating at up to  $-50^{\circ}\text{C}$ . The Arc7 ice classification also allows them to run without an escort in ice of up to 2.1m thickness. The ships are equipped with three Azipod propulsion units of 45 MW joint capacity, which is comparable to the capacity of an icebreaker. A new membrane-type gas containment system used in the cargo tanks, the GTT NO96 GW, has a total capacity of  $172,600\text{m}^3$  and ensures safe LNG transportation via the Northern Sea Route.

The implementation of integrated scientific research aimed at providing safe



Electrical power systems used on modern ice class ships under RS technical supervision



*Christophe de Margerie* was the first of the Arc 7 ice-classed series of gas carriers serving the Yamal LNG terminal

operation of the above marine transport systems, and developing the normative basis, are RS's biggest priorities. In 2017, RS implemented new requirements in relation to hull structure and the strength of the bow and stern ship ends using welded stems and sternframes. One particular research project focused on the creation of standards for the wear allowance value of the ice class ships' shell plating.

A further series of research projects in progress is investigating the development of requirements for the advanced electrical power systems used on modern ice class ships, including power distribution using

direct current. Mathematical model methods for mechanical tests of the shipboard electrical power plant sets are being implemented, allowing for the use of a numerical approach for the dynamic calculation of the structural strength of electric machines as an alternative to full-scale tests.

Other notable RS projects include the development of new specifications for the structure and strength of ships intended to operate astern propulsion in ice. Work is also underway into an ice class ship structure concept which proposes a hull shape significantly different from those currently in existence. **NA**

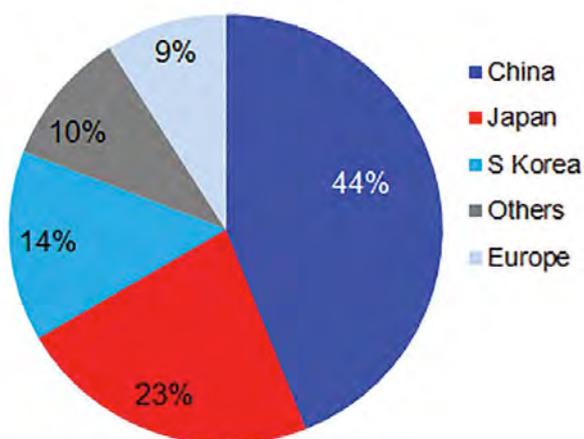


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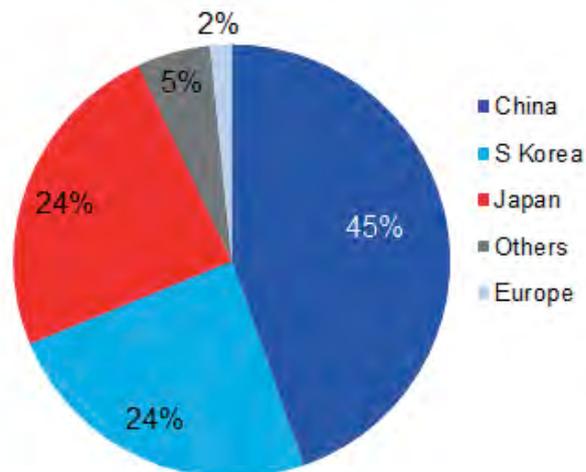
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	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half
VLCC >= 200,000	5	13	15	14	18	22	32	20	30	24	35	27	27	22
Suezmax 120-200,000	14	12	15	11	9	5	23	22	26	11	26	18	30	15
Aframax 80-120,000	29	21	29	27	26	42	63	33	39	31	28	31	30	15
Panamax Tankers 60-80,000	24	19	28	15	17	26	26	12	15	16	19	10	9	6
Products 30-60,000	60	55	72	70	73	92	92	67	66	46	45	27	27	30
Products 10-30,000	2	9	10	9	8	5	5	5	7	6	8	6	13	5
Chem & Spec. 10-60,000	55	44	59	62	83	103	106	70	75	60	53	41	39	9
Tankers < 10,000	26	30	31	47	62	92	71	70	65	50	53	52	69	34
Capesize > 100,000	32	26	31	26	21	24	33	77	101	112	128	122	148	65
Panamax 80-100,000	22	23	22	16	15	17	27	21	60	61	81	97	140	94
Panamax 60-80,000	36	26	22	22	23	20	18	15	18	33	36	44	53	39
Handymax 40-60,000	52	40	49	50	66	61	84	100	168	166	199	198	229	146
Handysize 10-40,000	39	38	47	63	75	74	116	156	162	169	172	172	220	116
Combos > 10,000	0	0	0	0	0	0	0	0	3	2	3	0	0	0
LNG Carriers	12	16	16	16	25	26	22	17	15	12	5	10	1	2
LPG Carriers	9	14	16	20	27	33	25	18	18	18	16	14	13	8
Containers > 8,000 teu	33	27	21	17	25	26	21	14	29	33	48	30	51	28
Containers 3-8,000 teu	45	53	58	73	69	62	59	59	77	41	31	21	39	19
Containers < 3,000 teu	90	113	107	124	137	109	69	53	54	26	33	30	33	38
Offshore	4	5	3	17	15	16	12	19	22	25	28	21	32	9
Cruise Vessels	6	0	7	3	6	3	3	6	9	4	4	2	6	1
Ro-Ro Ferries	11	5	12	10	21	6	11	8	10	13	10	9	11	8
Other	105	129	141	135	156	156	153	162	172	179	182	181	190	99
<b>TOTAL</b>	<b>711</b>	<b>718</b>	<b>811</b>	<b>847</b>	<b>977</b>	<b>1,020</b>	<b>1,071</b>	<b>1,024</b>	<b>1,241</b>	<b>1,138</b>	<b>1,243</b>	<b>1,163</b>	<b>1,410</b>	<b>808</b>

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14	6	4	13	22	10	31	22	36	28	73	33	11
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49	29	49	49	60	57	60	42	39	23	74	67	14
9	4	1	8	4	0	3	2	6	3	16	5	0
8	13	12	11	36	29	43	36	38	31	90	39	18
37	28	25	22	12	14	25	15	23	22	87	10	0
63	40	57	38	46	42	65	39	55	19	66	61	29
101	68	62	35	57	41	71	40	75	27	82	77	33
34	42	42	20	19	4	1	2	6	1	0	0	2
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4	13	14	19	16	16	15	18	20	12	71	33	7
22	16	14	14	25	40	49	33	45	18	37	28	5
51	33	59	42	58	62	37	26	34	35	88	23	26
46	29	26	25	18	6	2	0	2	4	26	0	2
29	17	22	27	27	35	39	24	35	36	125	79	17
12	19	32	30	25	14	25	21	18	21	88	29	13
6	0	3	2	5	1	8	2	7	3	18	20	15
6	6	12	6	12	6	6	16	21	9	43	16	6
98	79	72	63	66	48	50	58	45	46	171	72	13
<b>902</b>	<b>659</b>	<b>721</b>	<b>607</b>	<b>770</b>	<b>644</b>	<b>776</b>	<b>591</b>	<b>770</b>	<b>472</b>	<b>1,494</b>	<b>739</b>	<b>266</b>

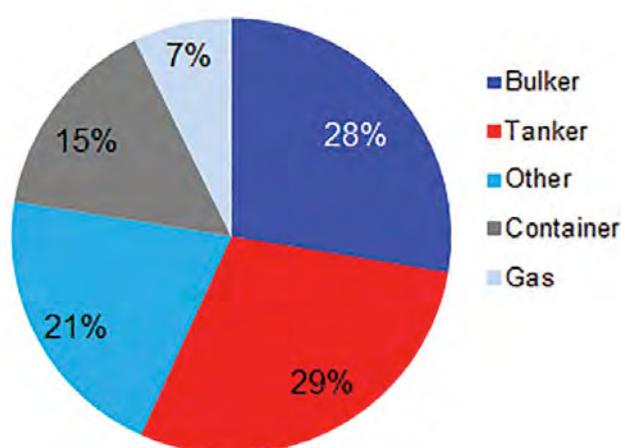
Data includes all vessels with LOA estimated at >100m

Where scheduled month of delivery is unknown an arbitrary month of build has been applied for orderbook data

The orderbook by year of delivery on this page is based on reported orders and scheduled delivery dates and do not necessarily represent the expected pattern of future deliveries

All data taken as of 1st January 2018

**Orderbook by Sector, No.**  
(Vessels > 100m LOA)



Source: Clarksons Research

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# A ballast from the past

Dear Sir

I read with interest the news item published in the January 2018 edition of *The Naval Architect* concerning Lloyd's Register's Approval in Principle (AIP) for a ballast free LNG carrier.

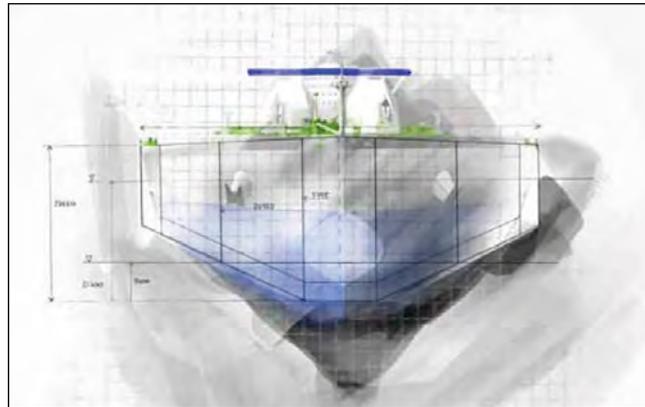
But this is by no means a new idea. In 1981 I joined DNV, as it was then, and one of my first tasks after training was to examine Crude Oil Washing (COW) and Clean Ballast Tank (CBT) manuals for approval, required for existing vessels obliged to meet MARPOL Annex I requirements.

It was my first experience of oil tanker operation and I was horrified by the large amount of oily water being generated and discharged into the sea. Furthermore, carrying large quantities of water ballast, in dedicated ballast tanks and cargo tanks for half the life of the ship, seemed like a complete waste of fuel.

Seeking a naval architectural solution, I felt that there must be a better way to satisfy the required minimum draft regulations without carrying water ballast. I believed it was achievable by adopting a trapezoidal shaped midship section, with a wider deck and narrower keel than a normal rectangular-shaped midship, with its sides sloping in to about 25°. I described this vessel as having a vee-form, rather like a 'V' with the point cut off (I assumed that the vee shape went up to the deck edge, but the freeboard could have been made vertical, without affecting the concept). Such a vessel would have the same  $C_p$  of a conventional tanker, but a much lower  $C_b$ .

Since draft is likely to be a constraining factor for oil tanker operations, I envisaged that this ballast free tanker would have either a wider maximum beam or increased length or a combination of the two, compared with a conventional tanker. But due to the distribution of steel, the neutral axis would be much closer to the half depth of the hull girder, leading to a more efficient hull structure and weight saving.

I was confident there would also be reduced fuel consumption in both the ballast and full load condition, as well as less hull tank maintenance. The only two significant problems that I perceived



Gone, but not forgotten: DNV's Triality ballast-free VLCC concept

were how to design the ship to have the desired trim in both the loaded and empty condition (a small amount of fresh water could be carried in the peak tanks for in-service trim adjustments) and how to berth against a conventional vertical jetty, if an offshore loading/discharge terminal was not available.

In order to demonstrate the viability of my idea, I submitted a proposal to DNV management outlining the research that I believed should be undertaken but, for whatever reason, it was not pursued.

In 1983, a US company, addressing the same challenge, put forward the idea, published in *The Maritime Reporter*, of an oil tanker with its round bilges cut away, with a chine in the bottom and side plates.

In 2000 I left DNV and shortly after a Swedish consortium came up with an idea for a ballast free tanker with a hull form similar to that suggested by myself, for the same reasons. But as far as I am aware, it did not result in any such vessels being built.

In 2010, with much publicity, DNV put forward its TRIALITY proposal, of which one of the three key features was its hull form, which apparently adopted the cut away bilge arrangement, in order to operate ballast free in the unloaded condition. However, it is doubtful they referred back to my proposal of 29 years earlier, when coming up with their design. As far as I am aware, no such vessels have been built.

In 2013, ClassNK announced its AIP for a Minimal Ballast Water Ship (or MIBS), VLCC design. It did not eliminate the

need to carry [sea] water ballast, only reduce the amount.

What does this all tell us about innovation within the shipping and shipbuilding industry? I do not claim to be the originator of the idea for a ballast free ship, as I am firm a believer in simultaneity. Within engineering and science it is not uncommon for different people and organisations to address the same problem, at the same time, and come up with similar solutions. For all I know, others may have come up with the idea before me, and there may be other similar proposals that have escaped my attention.

For example, there have also been proposals for a free flow ballast system where the sea water flows in at the bow and out at the stern; thus, in theory, water ballast is not being transferred from the cargo discharge port to the loading port, but this idea does not appeal to me as it appears to be a hull maintenance nightmare.

However, the consequences of the Ballast Water Management Convention, in my view, should provide even more impetus to creating practical ballast free ship designs, whatever the type of ship, to what was an existing challenge.

I just hope that I do not have to wait another 37 years before the idea I once had becomes a reality.

Yours faithfully,  
Jan van der Schans (MIRINA)  
Burnham-on-Crouch  
Essex

The Royal Institution of Naval Architects

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International Conference:

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By Chris Thomas

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Price: UK £9.00 EUR £10.00 OVS £12.00  
AMAZON PRICE: £12.74

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By Fred Walker FRINA

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Non-Members Part Ref: IJME18 Set Ref: ST118

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IJME - is published in March, June, September & December. The IJME provides a forum for the reporting and discussion of technical and scientific issues associated with the design, construction and operation of marine vessels & offshore structures



## International Journal of Small Craft Technology (IJSCT)

2018

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Non-Members Part Ref: IJSCT18 Set Ref: SS118

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<http://www.seatradecruiseglobal.com/>

## March 12-14, 2018

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[www.cmashipping2018.com](http://www.cmashipping2018.com)

## March 14-16, 2018

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International exhibition, Singapore  
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## March 21-22, 2018

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<http://maritime.knect365.com/shipping2030-global/>

## March 29-30, 2018

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## April 24-26, 2018

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[www.danishmaritimedays.com/](http://www.danishmaritimedays.com/)

## May 2-3, 2018

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International conference, Copenhagen  
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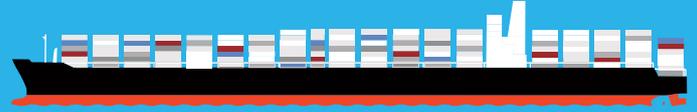


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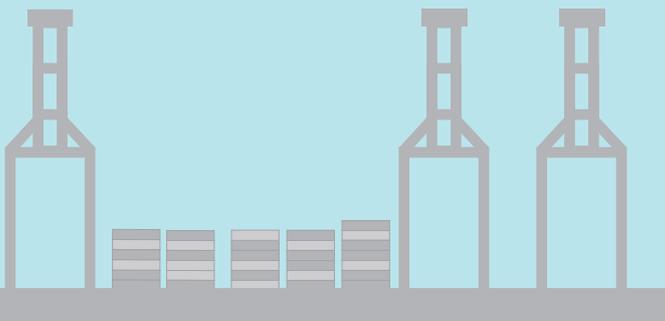
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