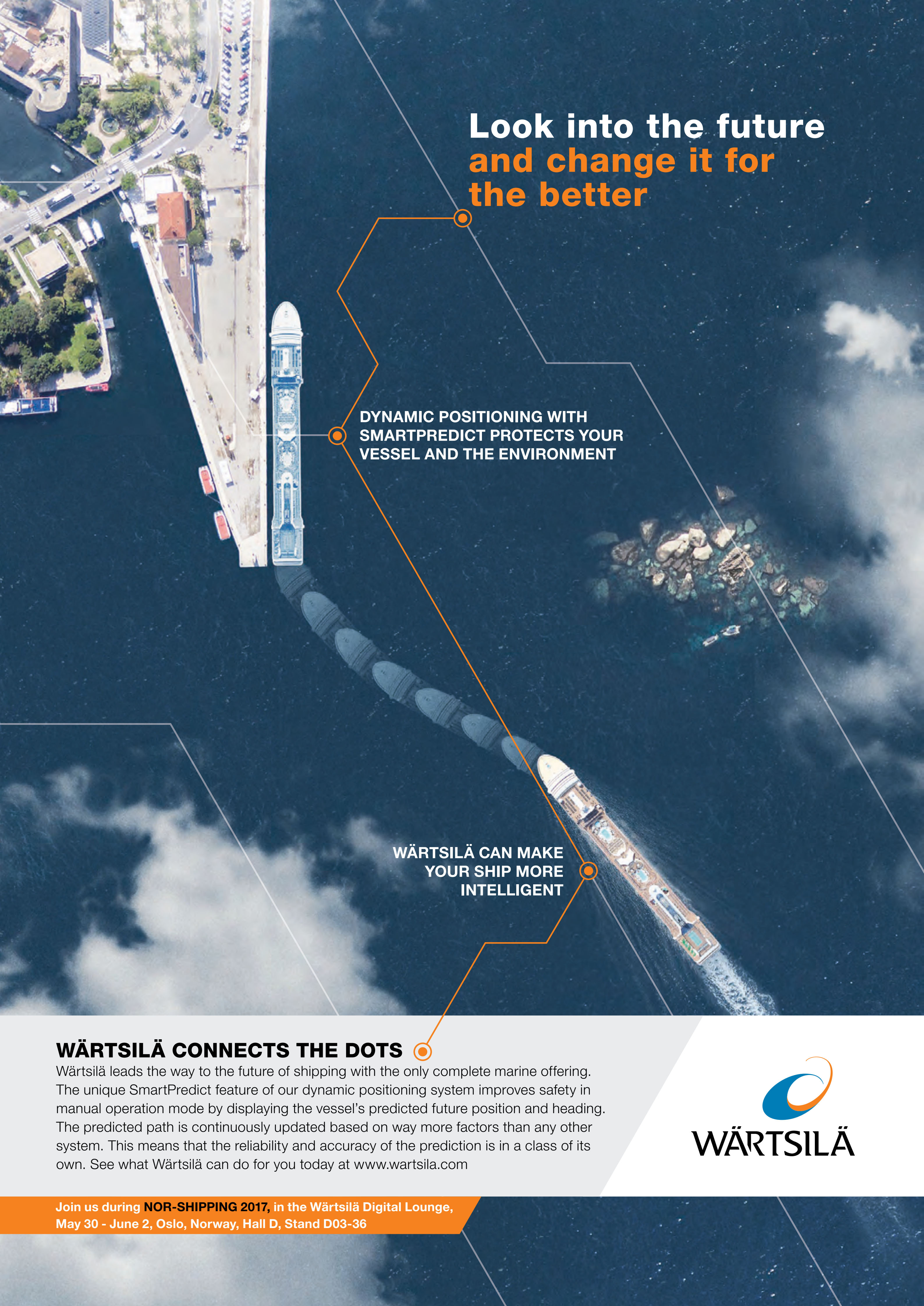
THE NAVAL ARCHITECT

International journal of the Royal Institution of Naval Architects | www.rina.org.uk/tna

Green ships / Norway / Ro-Ro / Smart ships / Noise & vibration / Cruiseships / **May 2017**


Look into the future
and change it for
the better
DYNAMIC POSITIONING WITH
SMARTPREDICT PROTECTS YOUR
VESSEL AND THE ENVIRONMENT
WÄRTSILÄ CAN MAKE
YOUR SHIP MORE
INTELLIGENT
WÄRTSILÄ CONNECTS THE DOTS
Wärtsilä leads the way to the future of shipping with the only complete marine offering. The unique SmartPredict feature of our dynamic positioning system improves safety in manual operation mode by displaying the vessel's predicted future position and heading. The predicted path is continuously updated based on way more factors than any other system. This means that the reliability and accuracy of the prediction is in a class of its own. See what Wärtsilä can do for you today at www.wartsila.com
WÄRTSILÄ
Join us during NOR-SHIPPING 2017, in the Wärtsilä Digital Lounge,
May 30 - June 2, Oslo, Norway, Hall D, Stand D03-36

Editor Richard Halfhide
Assistant Editor Robert Grisbrook
Design/Production Manager Sandy Defraine
Group Sales Director John Payten
Assistant Advertising Manager Valder Gates
Advertisement Production Manager Stephen Bell
Subscriptions & Publications Manager Jim-Ray Semanhyia
Publisher Mark J Staunton-Lambert

Published by:
The Royal Institution of Naval Architects
Editorial & Advertisement Office:
8-9 Northumberland Street
London, WC2N 5DA, UK
Telephone: +44 (0) 20 7235 4622
Telefax: +44 (0) 20 7245 6959
E-mail editorial editorial@rina.org.uk
E-mail advertising advertising@rina.org.uk
E-mail production production@rina.org.uk
E-mail subscriptions subscriptions@rina.org.uk

Printed in Wales by Stephens & George Magazines.

A 2017 subscription to *The Naval Architect* costs:

NAVAL ARCHITECT (10 issues per year)

12 months	**Print only†**	**Digital Only***	**Print + Digital**
UK	£182	£182	£232
Rest of Europe	£190	£182	£240
Rest of World	£204	£182	£254

†Incudes p+p
*Inclusive of VAT

The Naval Architect Group (English & Chinese Editions)
Average Net Circulation 16,694 (total)
1 January to 31 December 2016
ISSN 0306 0209

18 Full scale CFD on the up after successful workshop

YOUR PROPULSION EXPERTS

THRUSTERS TAILORED TO YOUR NEEDS

For powerful, cost-effective and efficient propulsion systems, the choice is clear... SCHOTTEL.

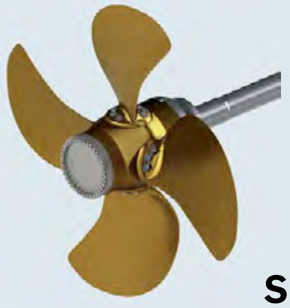
SRP

STP

SCD

SRE

SPJ



SCP

STT

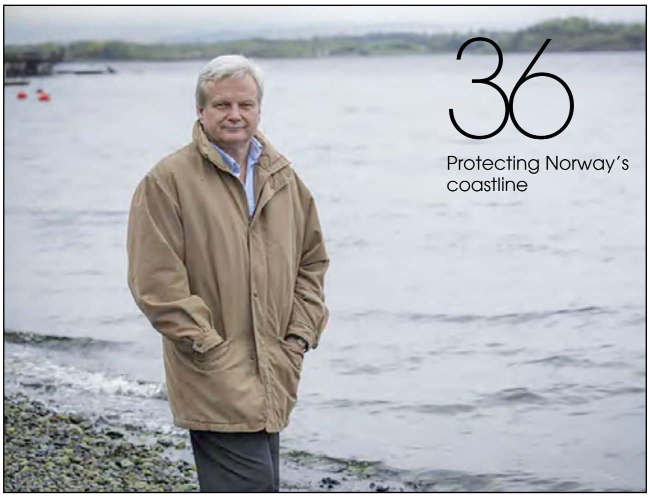
SRT

www.schottel.com

26-62 Features

42 Damage stability and *Estonia*'s legacy

33 New gas supply vessel design

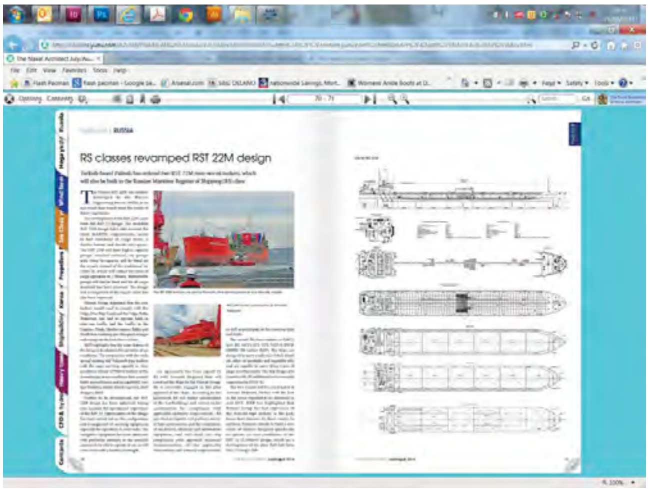

36 Protecting Norway's coastline

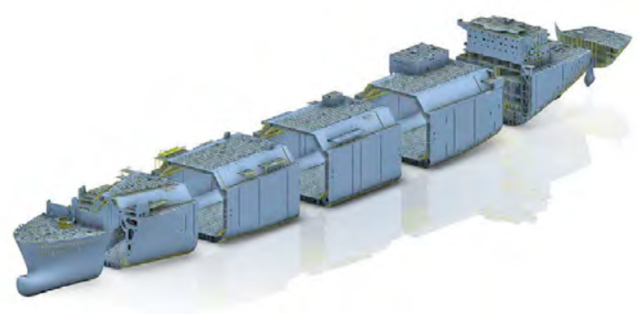

60 Cruiseships and the eco challenge

Digital Editions

The Naval Architect is published in print and digital editions. The current and archived digital editions (from January 2004) may be read on PC, iPad or other touchpad.

Visit http: www//rina.org.uk/Naval-architect-digital.html to read the digital editions, or download the free RINA Publications App.





Bigger, smarter, faster

BV's Veristar AIM3D combines a 'digital twin' with smart data

The term Big Data was first coined by NASA scientists in the late 90s to describe the challenge presented by the massive amounts of information generated by supercomputers. In effect, there was a disparity between the physical capacity to store data and the capability of the underlying infrastructure (e.g. operating systems, bandwidth) to process it. The notion that this raw material could be used for analytical purposes to identify trends was still in its infancy. Indeed, even the definition of what constituted 'big' back then seems a laughably small quantity today.

Nearly 20 years later, hardly a week seems to pass without another maritime equipment or service provider unveiling its own Big Data solution. Unsurprisingly, given the potential application for predictive maintenance and inspection, the classification societies are at the forefront of this push. Last month saw the launch of BV's Veristar AIM3D, a rival of sorts to DNV GL's Veracity platform and the Big Data collaboration between ClassNK and Fujitsu, both launched in the past year. Lloyd's Register meanwhile has yet to formally throw its hat into the ring with the comparable service for commercial shipping, but the acquisition of maintenance optimisation software company RTAMO in late 2016 was openly acknowledged by LR to be a precursor to that.

Given the vast sums that can be saved by marginal gains, the attraction of a meaningful Big Data solution as a means of optimising profitability is seen by its proponents as being self-evident. Hoever, Big Data remains a somewhat nebulous term. Depending on the particular stakeholder it might refer to the ship's performance, structural integrity, movements, emissions compliance, freight rates or even the monitoring of crew stress levels.

While it stretches credulity to think that an owner might invest in a solution that's not conducive with their own needs, anticipating the demands of future partners, for example freight operators, may not be so straightforward. Manifestly, choosing the right Big Data service is not the same as selecting a ballast water management system where performance can be judged according to a narrow set of parameters and equivalent results might be achieved by quite different methods.

> "Lack of standardisation in the formatting and structure of data has become the proverbial elephant in the Big Data room"

Discussions of Big Data generally make reference to what's known as the '4 Vs': Volume (the amount of data), Velocity (the speed with which the data is generated and can be used), Variety (the manifold formats the data may arrive in, sometimes incompatible) and, increasingly, Veracity (the trustworthiness of the data). The latter has been epitomised by concerns about the accuracy of onboard sensors, but it's surely Variety that will continue to pose the biggest headache. The lack of standardisation in the formatting and structure of data has become the proverbial elephant in the Big Data room and although progress is reportedly being made in the development of the Common Maritime Data Structure (CMDS) as part of IMO's e-navigation strategy, there's been little equivalent discussion of Big Data to date.

Moreover, there is a growing preference for the term 'smart data' instead, a qualitative approach that only analyses the most meaningful data. But there are drawbacks here as well; what if the methodology of said analysis is called into question or it becomes too reductive (collection bias)? The classification societies acknowledge that the lack of specialist maritime data scientists who can perform this kind of skilled analysis remains a challenge, but this can only really be solved with more specialised training at an academic level.

Both issues, the lack of standardisation and purpose-trained analysts are symptomatic of a technology yet to reach maturity and it goes back to the same challenge those NASA scientists had identified: the infrastructure cannot keep pace with the speed of change. Caution would seem advisory, but when it comes to gaining a competitive edge perhaps it's counter intuitive to think smaller. *NA*

Deliveries

Incat delivers new design

Australian shipbuilder Incat Tasmania is in the process of delivering a newly designed fast ferry to Danish operator Molslinjen.

Express 3 is a 109m wave-piercing catamaran capable of transporting 1,000 persons and either 411 cars or 227 cars with 610m of truck space at a service speed of 40knots.

It marks the start of a new generation of fast ferry designs from Incat's in-house naval architects, Revolution Design, utilising experience gained from the company's existing range of 112m fast ferries to meet a new design brief from existing customer Molslinjen.

"The design brief was simple," says Tim Burnell, spokesperson for Incat. "Ensure a consistent passenger experience and fleet commonality for Molslinjen, who already successfully operate two Incat 112m catamarans, whilst delivering a minimum 10% fuel and emissions saving plus faster vehicle deck turnaround times."

Express 3 during sea trials

The designers set about their task in a number of ways. To start, the 109m vessel design was made lighter, saving just over 100 tonnes at lightship weight, according to Incat. Vessel trim was also improved and the vessel's engine rooms were moved six frames further forward to improve speed and fuel consumption. In addition, a skeg was added to the keel of the ferry to improve directional stability.

Burnell adds: "the vehicle deck layout has been enhanced with a new two pillar line arrangement, offering an overall gain of 600mm width in workable vehicle deck space, greatly assisting loading and discharge, which in turn has a positive effect on turnaround times in port."

Built at Hobart shipyard, Tasmania, *Express 3* is scheduled to enter service on 1 June 2017.

Materials

Composite push from Southampton

The University of Southampton is calling for constraints on the manufacture and use of composite materials in the Marine, Rail, Oil & Gas and Construction industries to be removed to allow for growth in the UK.

A new position paper from the university, "Modernising composite materials regulations", proposes a way for industry to "migrate from current systems of assurance that are based on material 'equivalence' to the more effective 'performance' based system."

The contributing academics believe this migration "would harmonise the regulatory regime for composite materials across all the sectors and have a catalytic effect on the manufacture of composites in the UK".

They estimate that benefits of more than £4 billion (US$5.1 billion) could be seen in the UK by 2030 if industry and the UK government can work closely to overcome existing barriers.

"In the UK there is currently very limited coordination and centralisation of the codes and standards data associated with new composites," says Professor Simon Quinn, director of the university's Research Institute for Industry and lead researcher on the above-mentioned paper. "There is neither a coherent development of certified testing facilities nor a formal process for different sectors to share information and bet practice."

The paper calls for regulation to be centralised under the control of one government department. In theory, the lead department would work closely with the Composites Leadership Forum (CLF) and would oversee material regulatory policy, develop codes and standards, and authorise test centres in the UK and abroad.

A multidisciplinary team worked on the paper, including personnel from Southampton University's engineering; environment; business, law, and art (Institute of Maritime Law) faculties; as well as representatives from the university's Research and Innovation Services department and the Southampton Marine and Maritime Institute.

LNG

ECA compliant design gets AiP

Classification society ABS has awarded Approval in Principle (AiP) to a new dual-fuel bulk carrier


PALFINGER
LIFETIME EXCELLENCE
VISIT US
NOR-SHIPPING | OSLO
30.05.–02.06.17
BOOTH: C03-16
HARDING
WE HAVE EXPANDED
OUR FAMILY...
THE INTEGRATION OF HARDING SAFETY IS COMPLETED!
PALFINGER MARINE is the global leading manufacturer of highly reliable, innovative and customised deck equipment and handling solutions for the maritime industries. The product portfolio includes cranes, lifesaving equipment, winches and handling equipment. A worldwide service network including the supply of spare parts ensures fast and professional onsite support.
PALFINGER MARINE operates in all major maritime segments, including Offshore, Marine, Cruise, Navy and Coast Guard, and Wind.
CRANES
LIFESAVING EQUIPMENT
WINCHES AND HANDLING EQUIPMENT
PALFINGERMARINE.COM
zpirit.no

Seatransporter-DF, a dual-fuel bulk carrier design

concept developed by Algoship Designers Limited of Nassau, Bahamas.

Algoship's design, *Seatransporter-DF*, can help to meet current and upcoming international air emissions standards and can be used in Emissions Control Areas, and is capable of accommodating multiple engine types as well as either Type-C or membrane containment systems for LNG fuel.

Following work with US-based CleanShips LLC, a version of the design was made to meet specific operational requirements without compromising on cargo capacity. This 38,000dwt version is equipped with a 2,400m^3 containment system, but Algoship believes the same approach and dual fuel technology can be applied to Panamax, Ultramax and Kamsarmax size vessels.

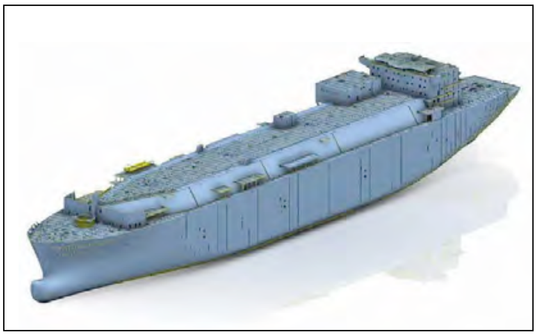
Dr. Kirsi Tikka, ABS executive vice president for Global Marine, says: "As industry considers future fuel strategies, design concepts that promote the use of LNG as fuel will play an increasingly important role in the mix."

Tools

BV launches Veristar AIM^{3D}

Bureau Beritas (BV) has become the latest classification society to unveil a data-based solution with the launch of Veristar AIM^{3D}, an asset integrity management (AIM) tool which combines a digital twin of marine or offshore assets with smart data.

BV's Veristar AIM^{3D} will enable real time collaboration during the design process and beyond



Based on the 3DEXPERIENCE platform developed by its partner Dassault Systèmes, Veristar AIM^{3D} has been conceived as a one stop shop for collaboration in the design stage, through construction and during the asset's operational lifecycle for predictive maintenance. BV believes that consolidating into a "single source of truth" will empower shipowners and technical managers to make smarter decisions through increased visibility of the actual asset and its performance. It estimates that the new tool will offer savings of 5% during the design and construction phase, a 25% saving in opex and a 25% drop in capex on repairs and refurbishment.

The digital twin on the 3DEXPERIENCE platform will be constantly updated to provide an evolving virtual model and enhance decision making about the asset's current and future condition. Accumulated data across these assets will in turn feedback into improved designs.

"This is what operators need today. Our priority is to support operators' opex and capex challenges while either maintaining or raising safety standards. This solution helps operators minimize risk and maximize return on their assets. Assets can now be designed and operated using digital capability," says Matthieu de Tugny, COO, BV Marine & Offshore.

BV also believes that it can solve the challenge of fragmented IT environments as Veristar AIM^{3D} will offer a means of interfacing with legacy systems and existing BV calculation tools. According to their particular level of authorisation, stakeholders will be able to view information on a bespoke online dashboard, with the potential for this to be segregated down to a single intervention.

Although BV currently prefers the term 'smart data' the core platform will be upscalable in anticipation of future demand for Big Data, the Internet of Things and Virtual and Augmented Reality.

José Esteve, AIMS director for BV, says the new tool goes far beyond the solutions currently on offer from rival class societies. "It will become the standard as it will be a disruptive business model." *NA*

Clarification

In April's feature "Green feeding from Denmark", a list of companies was presented in a note at the end of the article. The companies listed are specifically members who have been involved in the Regional ECOFeeder project. The full list of 45 Green Ship of the Future members can be found on their website.

Lessons must be learned from ore carrier sinking

The tragic loss of Polaris Shipping's *Stellar Daisy* is under investigation, and the structural viability of the whole VLOC fleet looks set to come under the spotlight, writes *Sandra Speares*.

The 1993-built, 266,000dwt VLOC foundered on 31 March with the loss of 22 members of her 24-man crew while on a voyage to China with a cargo of iron ore for commodities giant Vale. The vessel's flag state, the Marshall Islands, is tasked with the accident investigation.

The tragedy has brought the viability of the whole VLOC fleet into question, in particular those vessels that were originally VLCC conversions. The demands of the Chinese market for bulk commodities like iron ore in the years before the 2008 financial crash led owners to convert tankers to ore carriers to take advantage of the market boom.

Preliminary evidence from the surviving crew points to water ingress prior to the sinking, leading to a muster of the crew following possible structural failure. While not pre-judging the results of the inquiry, recovery of data may be a problem because of where the ship went down, making retrieval of the voyage data recorder difficult.

Considerable progress has been made in recent years to address the issues that led to so many bulk carrier casualties in the 1980s and 1990s. There is greater information sharing between key players in the industry and more attention paid to the importance of good maintenance and a robust inspection regime with the naming and shaming of shipowners who failed to ensure the safety of their crews and ships through poor maintenance and flag-hopping. However, critics continue to maintain that not enough has been done by the industry to improve bulk carrier safety.

Liquefaction has received increasing attention as a result of casualties like *Bulk Jupiter* in 2015 and initial comment suggested this might be the cause of the *Stellar Daisy* casualty. In the weeks since the accident the focus has turned to the dangers of converting ships designed for one trade to another, for example from VLCC to VLOC.

Tankers are longitudinally framed, as opposed to laterally in the case of bulk carriers. The conversion process necessitates substantial use of new steel to effect a transformation which involves cutting holes in the weather deck for hatches. What had been the tanker's centre tanks would be used to carry the cargo, with suitable reinforcement, while the ship's wing tanks would remain empty to provide buoyancy when the vessel was heavily loaded.

The transformation of *Stellar Daisy* from single hull tanker to bulk carrier carrying high density cargo will thus come under intense scrutiny in the light of what has happened. Not only will the investigation have to consider the work done to convert the ship and the testing procedures followed, but also problems experienced with other converted vessels in the fleet and maintenance and inspection programmes.

Whether further changes to classification societies' rules should be considered in the light of the investigation's findings is another question likely to be on the agenda.

The stresses and strains undergone by the ship during her life as a tanker would have been compounded by a different range of stresses and strains during her life as a bulker. Since the accident, problems with other ships in the Polaris fleet of VLOCs have been reported and the company has been carrying out inspections. There is also a substantial fleet of VLOCs in operation worldwide which started life as tankers. Analysts Alphabulk have estimated the number of VLCCs converted to VLOCs at just under 25% of the total.

International Association of Classification Societies secretary general Robert Ashdown commented: "As yet, IACS does not have sufficient confirmed information to comment or in any way speculate on the cause of the vessel's tragic loss. The Korean Register, as the classification society concerned, is in close touch with the Marshall Islands, as the vessel's flag state, who are working with other substantially interested states. The Korean Register and IACS are anxious and ready to make any relevant contribution to the formal investigation into the events and causes of this casualty. The Korean Register will study closely the findings of all appropriate enquiries into this casualty - and move to inform fellow members of the Association as appropriate and to incorporate any lessons to be learned that could further improve safety and minimise future risk from this type of accident."

INTERCARGO stressed lessons need to be learnt promptly after maritime casualties, adding that timely submission of the casualty investigation report to IMO is important as a means to identify the causes of the incident and enable corrective actions to be taken.

IMO secretary-general Kitack Lim added that "Thankfully these occurrences are rare; but when they do happen, they serve to remind everyone that the seafarers, on whom we all depend, do a difficult and sometimes dangerous job; and that those of us responsible for making the industry safer can never stop striving for improvements." *NA*

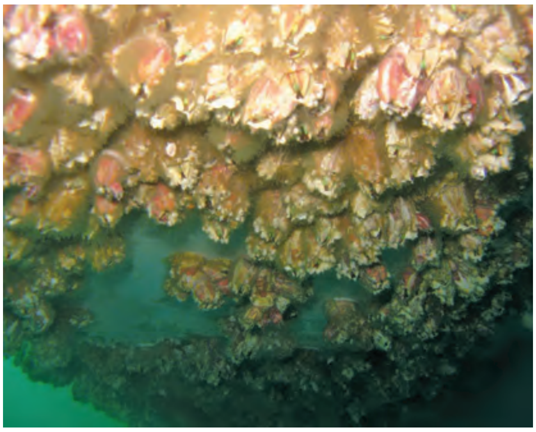
Coatings

Tin use in silicone coatings raises concerns

Leading hull coatings specialists have called upon the IMO to investigate the reports of the re-emergence of organotins in silicone-based foul release systems.

Organic derivatives of tin were largely outlawed after the ban on tributyltin in 2008 (TBT) due to its toxic effects on marine life; however some organotins, such as dibutyltin and dioctyltin, may still be used as catalysts providing that the allowable limit of 250mg/1kg of paint is not exceeded.

Dr Rik Bruer, a former researcher at the Netherlands Organisation for Applied Scientific Research (TNO), and now managing director of Finsulate, a manufacturer of non-toxic antifouling wrap said that in recent years higher quantities of organotins have started being detected again.



Barnacles on the bow. Organotins alter enzymes in molluscs

"About a year ago, I studied the Materials Safety Data Sheets of recent versions of these foul release coatings and it turns out that the amount of 'catalyst' added is more than 10 times higher compared to 2005. For me there is no debate that there is a purpose beside the catalyst activity and that the risk of spreading tin compounds again to kill marine life is eminent," says Bruer.

The effects of dibutyltin and dioctyltin have been proven to be similar to that of TBT, which can cause molluscs and other arthropods to change sex and have a catastrophic effect on marine ecosystems.

Boud Van Rompay, chairman of Subsea Industries, which manufactures the hull coating system Ecospeed, called for an immediate independent investigation, adding: "Like most people in the industry, we had thought the days of toxic tin in hull coatings was long gone. It is very worrying to hear this may not be so."

www.subind.net

Automation

Høglund wins automation contracts

Høglund Marine Automation has been awarded contracts to supply automations systems for an LNG bunkering vessel operated by Bernhard Schulte Shipmanagement (BSM) and two chemical tankers for Sirius Shipping.

The 117m BSM vessel, to be built at the Hyundai Mipo Dockyard and scheduled for delivery in late 2017, will be equipped with a variety of automation features by Høglund, including for the power management system and additional systems that handle the interactions between the ship machinery systems and cargo plant. As well as serving a consultative role during construction, Høglund will provide round-the-clock support when the vessel begins operation.

The Norwegian company has developed a particular niche within the emerging sub-sector of LNG bunkering vessels, having previously equipped smaller craft such as the Sirius-operated *Seagas* and Shell's LNG bunkering vessel currently under construction at STX in Korea. Unlike conventional LNG carriers, which can use boil-off gas, bunkering barges run off of vapours extracted when receiving ships are fuelled, which requires a higher degree of automation.

Høglund Marine Automation's CEO, Børge Nogva, says: "When creating automation solutions for an entirely new vessel sub-segment within LNG, it's hard to predict and foresee what challenges might emerge, which means you can't just use an off the shelf solution."

The Sirius chemical tankers, under construction at AVIC Ding Heng shipyards in China, will be equipped with automation that links the power management and cargo systems to improve efficiency during offloading operations.

www.hma.no

Hydrofoils

Hull Vane wins RINA award

The Royal Institution of Naval Architects' (RINA) 2016 Maritime Innovation Award was awarded to the patented

Hull Vane - a fuel saving device for fast displacement vessels

energy saving and seakeeping device Hull Vane at RINA's Annual Dinner in London on 17 April 2017.

Developed by Hull Vane BV, an independent subsidiary of Netherlands-based Van Oossanen Group, Hull Vane is a fuel saving device in the form of a fixed foil fixed below the stern of a ship. Its main markets include ferries, ro-ro's and cruiseships, as well as superyachts and offshore vessels. To date, 10 Hull Vane units have been sold.

The jury praised Hull Vane for its simplicity and effectiveness, noting its benefits in reducing pitching movements and increased operability of the vessel.

The Maritime Innovation Award, which is presented in association with technology company QinetiQ, acknowledges "outstanding scientific or technological research in the areas of hydrodynamics, propulsion, structures and material". Previous recipients have included manufacturers International Paint and Subsea Industries.

www.hullvane.com

Engines

WinGD picked for Aframax LNG engines

Winterthur Gas & Diesel (WinGD) has been awarded the contract to provide low-speed dual-fuel engines for a series of four LNG-fuelled Aframax crude oil tankers being built for SCF Group.

The Russian operator has chosen the seven-cylinder, 62cm bore type 7X62DF engines from WinGD's X-generation. It will be the first time that dual-fuel technology has been deployed on Aframax tankers.

"The order for the 7X62DF for the gas-fuelled Aframax tankers is a very clear message that our low-pressure lean burn technology is becoming the industry standard for all LNG-fuelled vessels, and not just LNG carriers," says Martin Wernli, WinGD CEO.

The 7X62DF engines are rated 13,800kW at 86rpm and capable of running on LNG, HFO, distillate or hybrid liquid fuels. In gas fuel mode they meet the requirements for IMO Tier III NOx compliance and IMO Tier II when running on liquid fuel. WinGD will also supply low-pressure selective catalytic reduction (SCR) after treatment systems for the 7X62DF engine to enable liquid fuel compliance. SCF estimates that SOx and NOx emissions will be 80-90% less than that of standard marine fuel, as well as a 15% reduction in CO_2.

The low-pressure gas admission technology also means the X-DF engines do not require high-pressure electrically-driven cryogenic pumps, which will reduce the installation cost.

Both the 7X62DF engines and the 114,000dwt tankers will be built in South Korea by Hyundai Heavy Industries. The vessels will be built to ice class 1-A and will operate primarily in the Baltic and North Sea regions.

www.wingd.com

Ballast treatment

USCG clarifies ballast position

The US Coastguard (USCG) has issued a clarification on its extension policy for vessels to comply with the ballast water management (BWM) regulations.

IMO's BWM Convention comes into effect from 8 September 2017, with shipowners and operators expected to have an approved ballast water management system (BWMS) installed at the time of the first International Oil Pollution Prevention (IOPP) renewal survey after that date. However, the matter has been further complicated by the USCG setting more stringent BWMS requirements for vessels in operating in its waters than those set by IMO.

The USCG now says that vessels with a compliance date before and including 31 December 2018 and that wish to apply for an extension will need to provide evidence why it is not possible for them to have an approved system installed before the deadline, for example insufficient time for installation or a suitable approved system not being available. In order to be granted an extension – which will be no longer than 18 months after the original date – shipowners will also be expected to provide a detailed strategy of how they expect to achieve the revised deadline.

Extensions for vessels with a compliance date between 1 January 2019 and 31 December 2020 will be assessed from the middle of 2018, dependent on changes in availability of USCG-approved systems. The USCG says it does not anticipate granting extensions for compliance dates beyond this point.

www.uscg.mil

Satellite communications

Intellian launches convertible VSAT

Intellian Technologies has announced a new satellite communications system that will allow users to access both the Ku- and Ka-band frequencies on the same antenna system.

The convertible v65 system is being promoted as giving fleet managers the flexibility needed as digital transformation and remote systems monitoring becomes increasingly pervasive across the industry. Built on the same as Intellian's GX60 terminal, which is currently deployed on vessels using Inmarsat's Ka-band Fleet Xpress service, Intellian says that for a "minimal investment" customers can acquire a compact conversion kit installable within 10 minutes.

www.intelliantech.com

Confidence builds in full scale CFD

Results are in for the first ever workshop on ship scale computer simulation. Dmitriy Ponkratov, senior consultant for Lloyd's Register's technical investigations department, discusses its conclusions

Many recent technical publications emphasise both the need for, and the validation of, ship scale Computational Fluid Dynamics (CFD). The value of CFD modelling to ship designers goes beyond predicting a ship's performance at the conceptual stage. It can be used to help identify causes of poor performance in existing vessels and to predict the effectiveness of energy saving measures that improve the hydrodynamics and aerodynamics associated with the vessel in question. Accurate ship flow modelling can also assist in failure investigations, such as propeller cavitation and other sources of ship vibration.

Figure 1: The first workshop in ship scale computer simulation organised by LR on 25 November 2016

Following international workshops on numerical methods in model scale ship flows that have been held regularly in Gothenburg and Tokyo, Lloyd's Register's (LR) Ship Performance Group has taken a step forward and organised the first ship scale hydrodynamics workshop. The objective of the workshop was to compare results of modern numerical methods with sea trials measurements completed by LR, and then to assess and develop the capabilities of the numerical tools in ship scale and to increase confidence in ship scale CFD.

The workshop was based on a comprehensive set of trials data (NA May 2016) obtained by LR in 2015 onboard the 16.9kdwt general cargo vessel *Regal*, for a voyage from Istanbul to Varna. The selected ship was an ideal candidate for CFD validation as she had a simple geometrical configuration: single screw, no thrusters, no bulbous bow, and no energy saving devices.

The workshop was announced by LR on 14 June 2016. Participants were invited to download the hull and propeller geometries of the subject vessel as well as the drawings and simulation conditions description which are identical to the sea trials records. The geometries supplied are based on 3D laser scans of the propeller and hull and were supplied in STL format.

Participants provided LR with blind numerical results for the subject vessel for self-propulsion, resistance, and the propeller's open water and cavitation conditions.

Four modelling scenarios were proposed:

1. **Ship scale resistance simulation** (four speeds). As there are no ship scale resistance measurements, all results were compared against each other.
2. **Ship scale propeller open water characteristics computations** (five speeds). As there are no ship scale open water propeller measurements, all results were compared to each other.
3. **Ship scale self-propulsion simulation** (three speeds). The results were compared with ship scale measurements performed by LR.
4. **Ship scale propeller cavitation** (one condition). The visual cavitation pattern was compared with ship scale high speed video recordings completed by LR.

Sixty sets of CFD results were received: seventeen for the resistance cases, nineteen for the propeller open water, twenty-two for the self-propulsion calculations and two for cavitation simulation.

The workshop took place on 25 November 2016 at LR's Global Technology Centre in Southampton, UK. Approximately seventy participants from fifteen countries attended the workshop.

As a validation example, Figure 2 represents a comparison of blind CFD results submitted by participants for the self-propulsion cases against measurements processed using the ISO15016:2015. This standard defines and specifies the standard to be applied in the preparation, execution, analysis and reporting of speed trials for ships, with reference to the effects which may have an influence upon the speed, power and propeller shaft speed relationships. procedure. The figure shows a noticeable scatter of CFD results due to the variation in CFD methods and settings employed by participants. Nevertheless, it is encouraging that some participants

submitted very accurate results; within 1% for both speed and power for all three power settings.

The following recommendations have been proposed as a result of lessons learnt from the workshop and can be considered a first step to guidance for ship scale CFD studies.

Geometry

3D laser scan geometry is considered to be a high quality source of geometric information as it represents the geometry of the as-built sailing vessel, removing the uncertainty of geometry created from design drawings. However, the direct use of scanned geometry for CFD may be challenging as some areas of high curvature are difficult to capture by the scanner (for example bilge keels). In order to use 3D scan data for CFD, it is recommended that the scan data is cut into sections and these sections are used to build the solid geometry, avoiding imperfections caused by the 3D laser scan.

Resistance calculations

Although ship scale resistance measurements were not available to compare with CFD simulations, it is recommended that the friction component of resistance is checked with friction line formulae proposed by various researchers. This check will indicate the acceptability of the CFD friction force.

As the contribution of aerodynamics drag from cranes to the total resistance in this case proved to be minor, it may not be necessary in the CFD setup. However, the superstructure should be included into the simulation as aerodynamic drag can add approximately 7% to the total resistance and also affect the dynamic trim angle.

It is recommended to use a free sink and trim setup for the resistance cases, as the difference in resistance between a fixed and free sink and trim setup was observed to be up to 3%.

Propeller open water calculations

The upstream shaft configuration that is preferred for propeller-hull interaction coefficients estimation is the recommended setup for CFD simulations.

A typical CFD setup for open water simulation assumes all blades are identical so the calculation is simplified to modelling a single blade in a sectored domain with appropriate periodic boundary conditions. However, in reality the blades may not all be identical (as demonstrated in the 3D scan of the subject propeller). It is recommended to perform simulations including all blades if the geometry is obtained from a 3D laser scan. For the geometry built by drawings it is acceptable to use a one blade configuration with periodic boundary conditions on the sides of the domain.

Self-propulsion calculations

The usual approach for undertaking self-propulsion simulations is to adjust the shaft speed until force equilibrium is achieved for a given ship speed.

If there is a requirement to carry out self-propulsion simulations for a fixed shaft speed and determine the ship speed, the following approaches should be considered:

- If reasonable computational power is available, it is recommended to run the self-propulsion cases with the ship free to surge, which allows an automatic correction for imbalance between the propeller thrust and effective ship resistance.
- A less computationally expensive approach is to run a number of cases with fixed shaft speed and varying inflow speeds, in order to build a thrust/effective resistance curve and derive the self-propulsion point. A final calculation should be completed to confirm the correct selection of speed.

A high resolution mesh is generally recommended for all CFD simulations. However, the results from the workshop showed reasonably good results can be achieved even with coarse meshes with cells counts as low as 10 million.

It is recommended to run the simulations with a free sink and trim setup. However, a workshop participant demonstrated that reasonable results can be achieved with a less computationally expensive approach by splitting the simulation into two parts: the first part is a resistance case with a fixed speed that is free to sink and trim; the second part is the self-propulsion case with applied and fixed sink and trim values from the resistance case.

A Sliding Mesh (SM) approach is recommended for self-propulsion simulations as it showed the best performance for this workshop case. However, it is acceptable to start the calculations with a Moving Reference Frame (MRF) approach. Other methods proved to be less accurate judging from the results of this workshop.

Figure 2: Speed and power results from measurements and blind CFD simulations

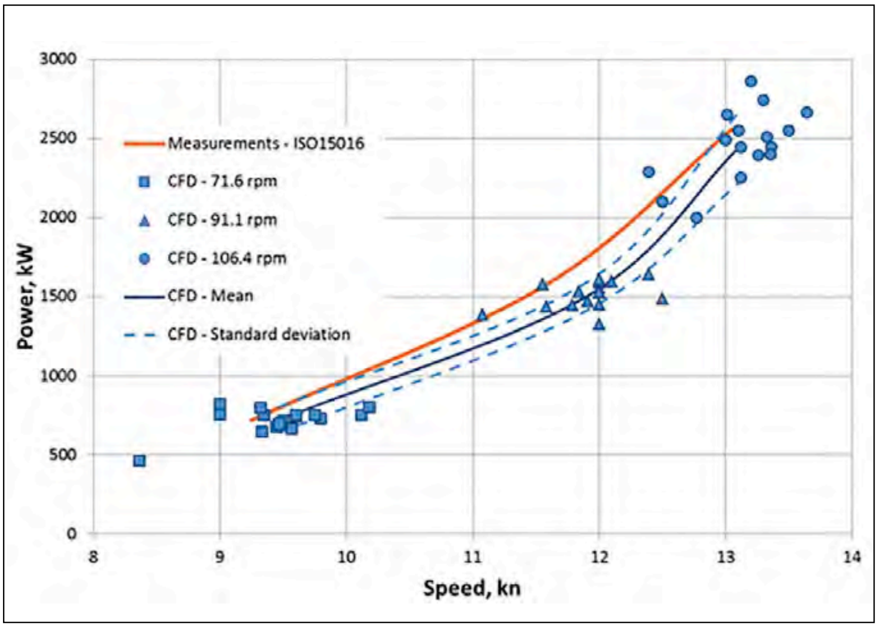


Figure 3: Ship scale CFD simulation of the subject vessel made with the STAR-CCM+ CFD code

It is recommended that a superstructure is considered in the CFD model, as the aerodynamic resistance contribution affects the dynamic trim. Additional data is required to determine a recommended value for the hull roughness.

Cavitation calculations

As the stern wave of a ship usually has a significant height, it is necessary to capture the shape of the stern wave, which will influence the hydrodynamic pressure on the propeller blades. In order to reduce the number of cells required for the simulation whilst taking into account the pressure effect of the stern wave, the whole analysis can be split into two stages. In the first stage of the analysis, the vessel flow can be calculated with the free surface in order to determine the shape of the waves. The cavitation model in this stage should not be active. Once the calculation is converged, the deformed free surface can be exported as a geometrical entity. This free surface geometry can then be used in the second stage of the calculation and set to an upper symmetry boundary. In this stage, the mesh can be refined around the propeller and the cavitation model should be active. This approach would also help to avoid numerical propeller ventilation which was seen by a number of participants.

All details of the CFD investigations can be found in the workshop proceedings available at info.lr.org/CFDworkshop. *NA*

A consequential ruling

Are shipbuilders liable for losses an operator incurs from a defective vessel? Tom Kelly, associate at global law firm Clyde & Co, considers the implications of the Star Polaris LLC-v-HHIC-Phil Inc case

On 17 November 2016, the High Court ruled that under the warranty clause contained in a shipbuilding contract, the obligation of the builder (shipbuilder HHIC-Phil) after delivery was limited to repairing any defects, and excluded any financial losses caused by the defect. This decision is of significant importance in the shipbuilding industry, since it could define the obligations of builders after delivery and limit builders' exposure to warranty claims more generally.

Clyde & Co's Tom Kelly

Star Polaris LLC-v-HHIC-Phil Inc (2016)

The warranty provided by the Builder in the case was on substantially the Shipbuilders' Association of Japan standard contract (SAJ form), with amendments. Perhaps most significantly, the usual wording excluding "loss of time, loss of profit or earning or demurrage" from article IX of the SAJ contract was not included in the warranty clause.

The amended Article IX.4 included the wording: *"Except as expressly provided in this Paragraph, in no circumstances and on no ground whatsoever shall the BUILDER have any responsibility or liability whatsoever or howsoever arising in respect of or in connection with the VESSEL or this CONTRACT after the delivery of the VESSEL. Further, but without in any way limiting the generality of the foregoing, the BUILDER shall have no liability or responsibility whatsoever or howsoever arising for or in connection with any consequential or special losses, damages or expenses unless otherwise stated herein."*

The Vessel (2011-built bulk carrier *Star Polaris*) suffered an engine breakdown during the warranty period, and while much of the damage was found by the Tribunal to be due to the negligence of the chief engineer (in failing to stop the engine while bearing wear alarms sounded), there was still a defect underlying that damage that fell within the warranty. The Buyer claimed for the cost of repairs, all of the lost time and profit during the period of repairs and an alleged reduction in value of the Vessel due to those repairs. The Builder agreed to pay the (limited) costs of repairs, but denied liability for all other losses.

On appeal from an Arbitration Award, the High Court (upholding the view of the Tribunal) dismissed the appeal and held that the reference to "consequential or special loss" in the context of Article IX excluded any and all losses caused by the defect, with the exception of the obligation to repair.

Key elements in the decision were:

1. It was common ground that the warranty clause provided a complete code addressing the obligations of the parties after delivery. The Buyer had to bring itself within that code in order to claim any remedy from the Builder. That concept had been raised in an earlier case, *Seta Maru*, in 2000, but doubts remained as to whether losses that resulted directly from a defect could still be claimed from the builder;
2. In Article IX.3, a distinction was made between necessary repair or replacement, which was for the yard, and any financial consequences such as the costs of bringing the vessel to a repair yard (which would ordinarily be "direct" losses) which were for the Buyer;
3. Article IX.4(a) contained wording expressly limiting the obligations of the Builder to those set out within the warranty.

Discussion

The argument in court was focussed on the meaning of "consequential loss". The general rule in English law is that this wording refers to losses where the parties had to have foreseen or had knowledge of that specific loss at the time of agreeing the contract. The Buyer therefore argued that this wording did not exclude losses that were caused directly by the defect, such as the lost time and earnings (at the current market rate) for the vessel.

The Builder argued (successfully) that the warranty clause was a completely new regime governing liability after delivery of the vessel. As a "complete code" it excluded all liability for breaches of the contract, and any right by the Owner to claim damages under English law. Instead, the warranty provided specific obligations for the Builder (to repair/replace defective parts and bear some costs) and unless the Buyer could show that the claim fell within the terms of the warranty, the Builder had no liability at all.

Specifically, the words "consequential loss" were something of a sideshow. Where all liability for the Builder was excluded by the "complete code", the specific additional exclusions within the warranty were not necessary. The Builder is responsible only for what it has expressly agreed to cover after delivery. What was, and is, crucial therefore is not any specific exclusions, but the establishment of the warranty as a complete code. Although this concerned specific contract wording, it is likely that the reasoning would apply to most SAJ form warranty clauses, meaning that great care is needed at the drafting stage.

If done correctly, both parties should have no doubts as to what is or is not covered in the event of problems following delivery. *NA*

船舶经济贸易
SHIP ECONOMY & TRADE

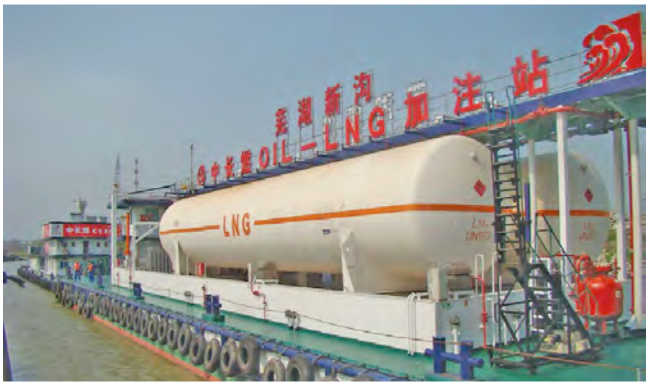
LNG forecast positive

Simultaneous development of LNG vessels and bunkering facilities is driving uptake of the alternative fuel

Speaking at the National People's Congress and the Chinese Political Consultative Conference, Tang Guanjun, director of the Yangtze River Navigation Bureau of the Ministry of Transport explained that inland, LNG-powered ship promotion and application is looking promising. In particular, the Yangtze River area is to build around 100 inland LNG vessels in 2017.

Of late, China's output of LNG-powered vessels has increased, both in terms of conversions and newbuilds. At the same time, LNG bunkering facilities and LNG bunkering pontoons have also gained impetus in development. On 20 December 2016, the bunkering pontoon *Haigang Star No. 2* set off on its maiden voyage. This vessel, measuring 136m long, 18m wide and 5.2m deep, has been called the biggest comprehensive bunkering pontoon for oil, water and gas in the world. It is equipped with two 250m^3 LNG tanks and provides LNG and high-quality refined petroleum products for vessels operating in the Yangtze area.

However, shipowners and operators of LNG-powered vessels are still concerned with the progress of developments: what comes first, the chicken or the egg? Should they wait for bunkering facilities to improve before building the LNG-powered vessel or should they build the LNG-powered vessels first and drive the gradual development of fueling facilities? For the Chinese market, the solution seems to have been to develop both areas simultaneously.



LNG infrastructure and vessel designs are being concurrently developed to encourage investment from all stakeholders in China

Progress made

China's inland vessel LNG research started in 2009, exploring concepts through to maturity. In 2014, the Ministry of Transport issued the *Waterway Industry LNG Pilot Project Implementation Plan* and *Pilot Project List for the Waterway LNG Application Project*. By the start of 2016, the Ministry of Transport clarified that the initial pilot project included 15 participants, and by October of the same year the Ministry announced a second project list, featuring nine candidate projects.

The first batch of pilot projects concluded at the end of last year. It successfully completed 72 vessels (out of 81 under construction) by this point, as well as 750 port-area LNG-powered vehicles, seven port-area LNG bunkering stations, nine inland LNG bunkering stations (with two more still under construction), and one mobile LNG bunkering pontoon (with another currently under construction).

Designs for subsequent pilot projects have either been finalised, are in the review process or are ready for construction.

Across China, the inland river segment has a total of 120 vessels powered by LNG, with the majority distributed around the middle and lower reach of the Yangtze River. More than 500 LNG vessels are scheduled to be built, while 10 LNG fueling stations are under construction in addition to two stations already in operation.

Managing change

With the constant development and construction of LNG-powered vessels and bunkering facilities, different standards and specifications were issued between 2009 and 2016. These included the LNG Bunkering Pontoon Classification and Construction Standard 2014 and LNG Inland Bunkering Pontoon Legal Inspection Temporary Rule 2014, which were consecutively issued. The successful installation and operation of the aforementioned inland LNG mobile bunkering pontoon was validated with publication of The Standard for LNG Bunkering Pontoon, while offshore LNG-powered bunkering procedures were also legalised. Last year saw standards published for LNG dock design and inland LNG bunkering pontoon dock design, with CCS issuing its 2017 LNG Bunkering Pontoon Standards at the end of last year.

Related equipment and technology was also focused on in this period. Domestic engine builders developed an LNG-single-bunkering engine with different powers and an LNG/diesel dual fuel engine, while equipment manufacturers developed numerous technologies including control systems, security alarm systems, exhaust systems, and LNG tanks.

LNG bunkering technology has also progressed. A pilot project in Zhoushan is investigating synchronised bunkering for multiple vessels and the different services an LNG-bunkering pontoon will have to offer to domestic and international LNG-powered vessels, such as the pre-cooling of its liquid cargo and bunkering capabilities. The design and bunkering technology for this pontoon has been patented by China Classification Society.

Looking to the future, Tang Guanjun says that in the process of promoting inland LNG vessel, the layout of bunkering stations will be further optimised. In addition, according to the experts from Marine Transportation Technology Center of Waterborne Science Institute of Ministry of Transport, the second batch of pilot LNG projects (revealed in October 2016) will have distinctive research interests, including an LNG-powered passenger vessel and the overall replacement of LNG tanks for LNG vessels. *NA*

Seawork International is the largest and fastest growing commercial marine and workboat exhibition and conference in Europe

Sea WORK 2017 INTERNATIONAL

20th ANNIVERSARY

Aerial image credit: Panoptic Motion

REGISTER NOW at SEAWORK.COM

13-15 June 2017

Mayflower Park, Southampton, UK

- Providing a one-stop shop for 7,600 buyers and maritime sector specialists
- Discover 10,000 products and services with over 600 international exhibitors in attendance
- Walk on and trial more than 70 vessels and floating plant on the pontoons
- Learn from industry leading experts in topical seminars
- Find a plethora of pavilions and trails across many industry sectors
- Events and demonstration schedule from true innovators in the marine industry
- Network with maritime professionals at a host of events

Contact info@seawork.com or +44 1329 825335

seawork.com

Over 50 supporting organisations including:

CBOA freight by water – Commercial Boat Operators Association

Royal Instituion of Naval Architects

SSA The Voice Of The UK Marine Industry – Shipbuilders & Shiprepariers Association

International institute of Marine surveying

International Harbour Masters Association

nwa – National Workboat Association

mercatormedia magazines | events | online

Fighting the windbreak

A new study explores market opportunities and market barriers for wind propulsion technologies for ships, and challenges the idea wind propulsion is only for slow steamers. Jonathan Köhler, Dagmar Nelissen and Michael Traut of CE Delft University summarise their findings

According to the most recent estimates, global shipping emitted on average about one billion tonnes of carbon dioxide annually in the period 2007–2012, equivalent to just over 3% of global anthropogenic emissions (UCL, CE Delft et al., 2015). This share is, despite market-driven and regulatory efficiency improvements, expected to increase significantly in the future, due to the growth of the sector and due to the emissions reductions that can be expected to be achieved by the other sectors. Measures that can significantly reduce the CO_2 emissions of the shipping sector will therefore play a major role in a 'fair share' of the global emissions reductions necessary for meeting the challenge of climate change.

A range of measures including slow steaming and renewable energy sources will be needed to de-carbonise maritime transport. Wind propulsion technologies for ships have two advantages: they have nearly zero emissions and they have zero fuel costs. Many innovative wind propulsion technology concepts have been and are being developed for commercial shipping. However, none of the technologies have reached market maturity yet. There are currently two providers of wind propulsion technologies for ships whose products are close to marketability and there are up to 24 additional wind propulsion technologies/ concepts relevant for the aim of this study that may become available by 2030.

The study we have carried out estimates the market and emission savings potential of the wind propulsion technologies for 2030, as well as the economic and social effects associated with this market potential. It identifies both the barriers to the development and uptake of wind propulsion technologies and the possible actions that may contribute to overcoming them.

Power savings from wind technologies

Four technology types were modelled: rigid/ wing sails, towing kites, Flettner rotors and wind turbines. Power savings on a ship level have been calculated for six sample ships. These include three ship types (tanker, bulker, containership) and two different ship sizes respectively; two alternative vessel speed regimes were accounted for (Table 1).

Table 2 shows the dimensions of the devices for the different sample ships. In each case, the technology models yield an instantaneous thrust force, a side force, and power consumption or production, as a function of ship speed, ship course, and wind velocity.

Satellite tracking data of individual ships (AIS data) was then used to determine operational profiles. For each sample ship type, both terrestrial and satellite AIS messages were collected for a set of vessels of the same type and similar size. The AIS data covers a full year. For each vessel, AIS messages were time-ordered, subjected to a quality filter discarding faulty messages, and complemented by a path-finding algorithm where there are gaps in coverage, assuming the shortest routes between two geographical locations. Every location report with the ship active was considered part of the operational profile, and weighted by the time difference to the preceding AIS report (so as not to

Category	Bulker	Bulker	Tanker	Tanker	Container	Container
Size	7,200 dwt	90,000 dwt	5,400 dwt	90,000 dwt	1,000 TEU	5,000 TEU
Service speed	13.25 kts.	14 kts.	13.8 kts.	15 kts.	17.55 kts.	24.9 kts.
Main engine power	2,802 kW	8,445 kW	2,827 kW	12,850kW	10,166 kW	47,744 kW
Length	107 m	244 m	97 m	231 m	138 m	286 m
Beam	18 m	40 m	17 m	42 m	23 m	32 m
Depth	9 m	21 m	8 m	21 m	12 m	21 m
Fast voyage	12.3 kts.	12.3 kts.	13.0 kts.	13.0 kts.	17.5 kts.	19.0 kts.
Slow voyage	10.5 kts.	10.5 kts.	11.0 kts.	11.0 kts.	14.9 kts.	16.1 kts.

Table 1: Overview of sample vessels' main particulars and voyage speeds

Technology / Ship	Parameter	Container, 1,000 TEU	Container, 5,000 TEU	Tanker, 5,400 dwt	Tanker, 90,000 dwt	Bulker, 7,200 dwt	Bulker, 90,000 dwt
Rotor	Number	x	x	2	3	2	3
	Height			22m	48m	24m	48m
	Diameter			3m	6m	3.5m	6m
Kite	Number	1	1	1	1	1	1
	Area	$400m^2$	$400m^2$	$400m^2$	$400m^2$	$400m^2$	$400m^2$
Sail	Number	x	x	3	5	3	5
	Height			25m	50m	27m	50m
	Width			9m	17m	10m	18m
Turbine	Number	x	x	1	3	1	3
	Height			20m	20m	20m	20m
	Diameter			38m	38m	38m	38m

Table 2: Mapping of the number and size of technology devices to sample vessels

give undue weight to periods with frequent messages/high coverage vs periods of infrequent messages/low coverage).

Wind data for each operational profile was read from weather statistics from the ECMWF weather forecast data service. This provided data at six hour intervals on a 10m-high 0.125°x 0.125° grid covering the earth. Since wind speed varies with height above sea level, an adjustment was made following the assumption that the wind speed profile follows the power law: $\nu/\nu_{10m} = (h/10m)^P$ with an exponent P = 0.11. The effective wind speed applied in the rotor and the rigid sail model was calculated as the average of the adjusted wind speed over the height of the installation, from a base height of 10m. The effective wind speed for the kite model is calculated at the height of the centre of the kite's circular flight pattern according to the above power law. The wind data was then integrated over the operational profile to calculate annual power savings. For the six sample ships and the selected dimensions of wind propulsion technologies, relative power savings across the AIS-recorded voyage profiles (see Table 3) were found to be comparable for Flettner rotor and wing sails. For towing kites, relative savings were, by comparison, higher for smaller vessels and lower for larger vessels, while relative savings were lowest for wind turbines.

For all technologies it holds that relative savings (savings as a % proportion of the normal power requirement) are higher for the lower speed which can be expected due to the much lower power demand at the lower speed. However, for absolute savings (expressed in kW in Figure 1) this does not hold true. Absolute savings tend to be equal or even lower at the higher speed for the towing kite and the wind turbine, and absolute savings for the wing sail and the rotor are larger at the higher voyage speed for all ship types considered.

This is a very important finding, as it implies that a barrier to the adoption of wind propulsion has been overestimated: ships do not necessarily need to slow down for at least some wind propulsion systems to become cost efficient. Relative savings of rotors and wing sails on the larger ships exceed relative savings on the smaller ships, especially on the bulk carrier. In part, this is due to the fact that large vessels make more open ocean voyages on routes where they experience higher wind speeds than smaller vessels. In addition, larger vessels can be equipped with more and taller wind propulsion devices, harnessing additional effects from the higher wind speeds experienced by the taller devices.

The gathered results clearly indicate the significant savings potential from the considered technologies, even in a business as usual mode of ship operations.

Table 3: Average relative savings across the AIS-recorded voyage profiles – higher speed

	Rotor	Wingsail	Towing kite	Wind turbine
Large bulk carrier (90,000 dwt)	17%	18%	5%	2%
Small bulk carrier (7,200 dwt)	5%	5%	9%	1%
Large tanker (90,000 dwt)	9%	9%	3%	1%
Small tanker (5,400 dwt)	5%	5%	9%	1%
Large container vessel (5,000 TEU)			1%	
Small container vessel (1,000 TEU)			2%	

Market potential and economic effects

A dynamic model was developed to model the adoption of wind technologies over time and

the resulting fuel and CO_2 emission savings they provide. The model factors learning effects into its calculations. It allows for cost reductions as increasing numbers of systems are deployed and uses investment costs that were taken from estimates provided by wind technology developers.

The model has two main components: a payback calculation which determines the decision to adopt wind technologies or not and a scenario of the overall fleet size for the different types and sizes of ships considered. This made the following assumptions:

- required payback time to decide to install the WPTs: five years;
- discount rate for future cash flow: 5% p.a.;
- HFO price: $450 per tonne in 2020, increasing to $550 per tonne in 2030.

Fleet sizes are estimated using Clarkson's data for newbuildings history and current order books and the longer term scenarios of IMO (2014).

For these assumptions, should some wind propulsion technologies for ships reach marketability in 2020, the maximum market potential for bulk carriers and tankers is estimated to be approximately 10,700 installed systems by 2030, including both retrofits and installations on newbuilds. The use of these wind propulsion systems would then lead to CO_2 savings of around 7.5 million tonnes CO_2 in 2030 (approximately 0.7% of total global shipping emissions) and the wind propulsion sector could provide around 8,000 direct and around 10,000 indirect jobs.

The diffusion process will however not have reached maturity in 2030; this is expected to occur around 2040, when more newbuilds have entered the fleet (retrofits are more expensive than installation on newbuilds) and capital costs have further declined due to learning effects and economies of scale. It is important to note that these results are a conservative estimate; they represent the impact of current, relatively small scale installations on current ship designs and operating patterns.

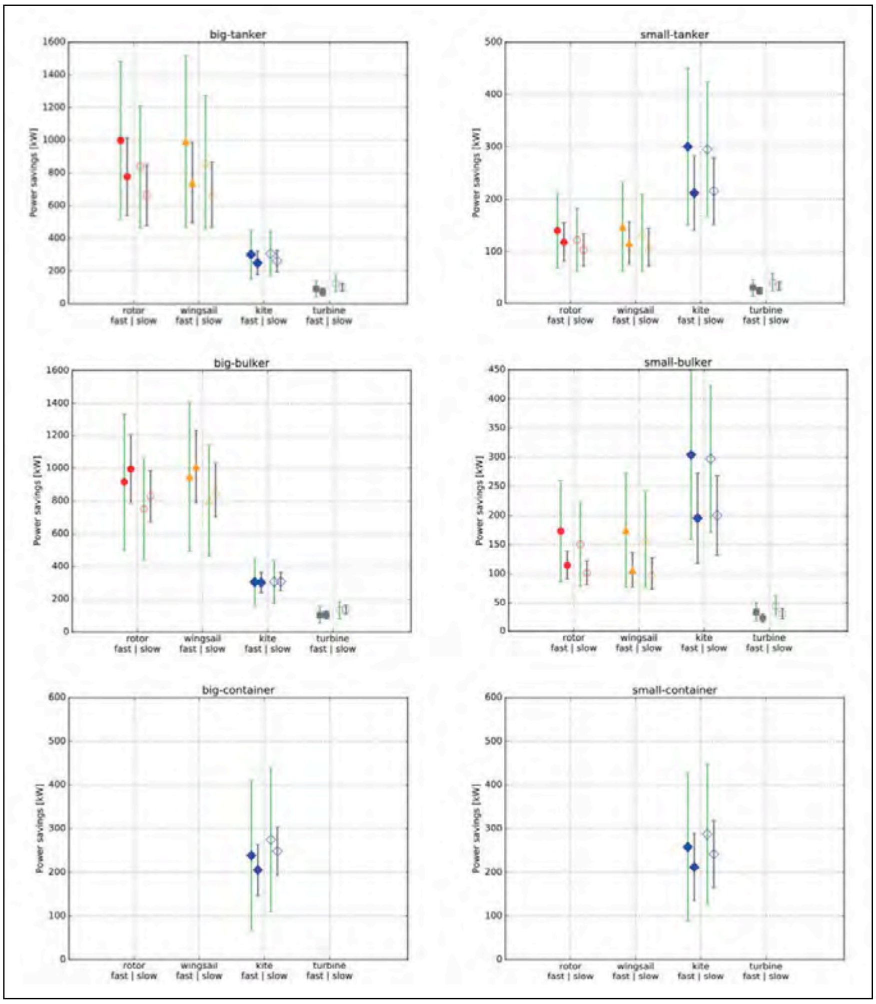


Figure 1: Average absolute power savings averaged over the sample fleet's voyage profiles from AIS tracks (solid symbols show savings for the higher speed, empty symbols show savings for the lower speed)

Barriers to uptake

Several barriers have been identified that currently prevent the further development and uptake of wind propulsion technologies (WPTs) in general. Regarding uptake, these are:

1. Technical characteristics can limit the applicability of the technologies, with retrofits naturally being more restricted than newbuilds e.g. requirements for deck space and access for wind rigs.
2. Factors that have a negative impact on the cost efficiency of WPTs by negatively affecting their benefits, performance or costs (e.g. low bunker prices).
3. Factors that contribute to the uncertainty of their cost efficiency. Some of these uncertainty factors cannot be alleviated (e.g. fuel price volatility or economic cycles), whereas other factors are uncertain (actual performance due to the natural variability of winds) because there is insufficient reliable data on the performance, operability, safety, durability, and economic implications of wind propulsion.
4. Access to capital for the uptake of WPTs.

In addition, there are barriers to the uptake of cost efficient abatement measures in general, for example the split incentives between the shipowner and the operator or the scepticism of the sector to changes that require major alterations to operations and organisation.

Barriers specific to the (further) development of WPTs include: access to capital for the development of WPT, especially for building and testing of full scale demonstrators, and the current legal/institutional framework. Wind technologies have not yet convinced the shipping industry in general that they offer reduced operating costs and can show a convincing financial case for investment. This makes capital difficult to attract, especially as there is limited investment in tankers and bulkers. The current institutional framework often penalises late arrival at destination ports, with no charter mechanisms to allow


MARINTEC CHINA 2017
The All China Maritime Conference & Exhibition
二O一七年中国国际海事技术学术会议和展览会
5-8 December 2017
二O一七年十二月五至八日
Shanghai New International Expo Centre
上海新国际博览中心
STRENGTHENING
壮大
LEADING
引领
CONNECTING
互联
marintec China
Organised and Managed by 承办单位
UBM
博闻
SSNAOE
上海市船舶与海洋工程学会
UBM
Sponsored by 主办单位
Ministry of Industry and Information Technology, PRC
中华人民共和国工业和信息化部
Shanghai Municipal People's Government
上海市人民政府
Co-sponsored by 协办单位
China State Shipbuilding Corporation
中国船舶工业集团公司
China Shipbuilding Industry Corporation
中国船舶重工集团公司
China Association of the National Shipbuilding Industry
中国船舶工业行业协会
Chinese Society of Naval Architects & Marine Engineers
中国造船工程学会
www.marintecchina.com

Ship type	Build Type	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Tanker (5,000-120,000 dwt)	Fleet	2,892	2,915	2,938	2,961	2,984	3,008	3,022	3,036	3,050	3,064	3,078
	New build with sail	0	20	64	149	199	206	201	205	206	207	208
	Retrofit with sail	15	22	126	197	199	201	201	202	203	204	205
Bulker (0-100,000 dwt)	Fleet	10,718	11,231	11,743	12,256	12,768	13,281	13,914	14,547	15,180	15,813	16,446
	New build with sail	0	30	172	497	459	608	712	723	723	734	662
	Retrofit with sail	0	22	126	409	426	443	464	485	506	527	548

Table 4: Predicted number of ships fitted with sails between 2020 and 2030

for variable passage times. Also, the operation of ships with wind technologies is no longer familiar to the cargo shipping industry, making an assessment of necessary procedures for safe operation difficult.

The following three barriers have been identified as key:

1. Reliable information on the performance, operability, safety, durability, and economic implications of the WPTs.
2. Access to capital for the development of WPTs, especially for building and testing of full scale demonstrators.
3. Incentives to improve energy efficiency/reduce CO_2 emissions of ships.

These key barriers are interrelated in different ways, with the most crucial interaction being a chicken-and-egg problem between information and access to capital.

Actions

In order to resolve this chicken-and-egg problem, the most important starting point is to devise a standardised method to assess WPTs, and to combine them with test cases to develop the agreed assessment method. When developing a standardised method to assess WPTs, the consistency of the (to be developed) Energy Efficiency Design Index (EEDI) technical guidance for the conduction of performance tests of wind propulsion systems should be considered. The evaluation method should not be restricted to the determination of the available effective power of the systems, but should also include the determination of the actual fuel savings.

When a standardised assessment is established, measures requiring the reporting of information on the performance of WPTs and access to this information can be introduced. For example, within the framework of the EU monitoring, verification and reporting (MRV) regulation, ships should be given the opportunity to publish the use of innovative energy efficiency measures. These can be accompanied by support for access to capital for the development and testing of full scale demonstrators. Testing of demonstrators e.g. the Flettner installation on the cruise ferry *Viking Grace* (NORSEPOWER, 2017) should yield information generated by an independent party, to convince shipowners and investors and to create a real value added from public funds.

International policy and, if there is limited progress at the IMO level, EU and regional policy similar in geographical coverage to the ECAs, can provide a reliable framework for investment.

There are available public funds that finance, amongst other things, demonstration projects in the maritime shipping sector, but in order to improve access to capital for companies that want to demonstrate the performance and operability of energy efficiency measures for maritime transport, the following actions could be taken:

- Offer a payment scheme that is viable for small and medium-sized enterprises (SMEs);
- Keep the administrative effort as low as possible without compromising accountability;
- Offer programmes aimed specifically at demonstration projects for maritime ship-ping;
- Offer programmes aimed at demonstration projects for maritime shipping without narrowing down the eligible technologies beforehand.

In summary, wind propulsion technologies have the potential to make major reductions in both greenhouse gas emissions and SOx, NOx and particulate emissions. The reduction in energy demand for operation may in the next few years make a financial case for investment under reasonable assumptions. The technology has reached the demonstration stage, but there are still major barriers to the uptake of these technologies. If these policy and market barriers can be overcome, shipping will be able to adopt wind propulsion technologies on a large scale. *NA*

Note

This article is based on the paper: "Study on the analysis of market potentials and market barriers for wind propulsion technologies for ships," 16.7G92.114, CE Delft, Delft.

www.cedelft.eu/publicatie/study_on_the_analysis_of_market_potentials_and_market_barriers_for_wind_propulsion_technologies_for_ships/1891

Authors of the paper

Dagmar Nelissen, Michael Traut, Jonathan Köhler, Wengang Mao, Jasper Faber, Saliha Ahdour

Supply revolution: waiting but not wanting

Mid-term supply solutions may bridge the gap while LNG infrastructure and gas-ready ship orders grow

Angus Campbell, corporate director of energy projects at Bernhard Schulte Shipmanagement (BSM), discusses a new gas supply vessel (GSV) design and how vessels of its kind will facilitate the practical adoption of LNG fuel in an exclusive Q&A with *The Naval Architect.*

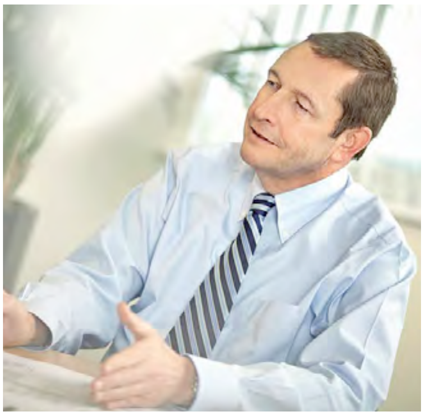
NA: How will GSVs fit into the wider adoption of LNG?

AC: We view GSVs as a critical component of the infrastructure needed to allow the shipping industry to utilise a cleaner burning fuel. Until the number of ships ready to burn gas as a primary fuel increases, acceptable utilisation will be a commercial hurdle that we need to overcome. Because of this, our newly designed GSV will be able to function as a highly capable fuelling vessel, but will also be able to tranship LNG to other shore-based users. As to the wider adoption of LNG as a marine fuel, each GSV will increase fuel availability and build confidence in the end user's mind that resupply will be available where and when it is needed to support the venture.

NA: What infrastructure is needed to support vessels of this type and wider LNG logistics?

AC: The best way to explain this is to use the analogy of infrastructure changes needed when the shipping industry moved from using wind for propulsion to using coal, followed by the more recent transition from coal to oil.

In both cases, new 'bunkering' infrastructure was necessary to support the change. As we move from oil to liquefied natural gas, the cryogenic storage and small ship loading facilities in major bunkering centres around the world will be needed once again. Investment on this scale will take time,



Angus Campbell, BSM

so for the foreseeable future we believe that GSVs that can serve a region rather than just a single port will be called for. As mentioned before, this will also help to increase utilisation and make the service commercially viable. Small ship loading facilities are being developed in many terminals to allow LNG bunkering vessels like the GSV to lie alongside safely. Many LNG terminals were designed for larger ships, with fendering and manifold height designed accordingly.

NA: Who has collaborated on the design?

AC: The design has involved a number of world class companies. In addition to Babcock Schulte Energy (BSE) which harnesses the expertise of Schulte Group and Babcock (including Babcock LGE Process), the conceptual design was developed by BMT TITRON.

BMT TITRON fully supported the design. This support ranged from work on the original concept, including design to Class requirements for the first, Black Sea and Danube-tailored design (a design that has not gone ahead), through to the current GSV whereby the detailed design was taken over by the current builder. This design is now coming to fruition because of the skill of Hyundai Mipo Dockyard (HMD) in the construction phase. As you can imagine, the first-in-class design is evolving as we progress using the combined experience of the parties involved.

NA: What is innovative about it?

AC: We have used a fresh design approach. It not only operates safely, efficiently and with high manoeuvrability, but also ensures that all boil off and flash gas generated during fuel transfer is retained onboard the GSV. This stored gas is then compressed and used as fuel to produce power in an effort to reduce fugitive emissions to zero, protecting the environment. The design has also removed the need for ballast exchange, using trim tanks with passivated water only.

The GSV will be classed by Lloyd's Register, possess Ice Class 1A FS, and will be fully compliant with the revised IGC Code. Its main dimensions are 117m LOA, 20m beam and design draught 5.2m salt water. Cargo capacity in two independent Type C tanks is about 7,500m^3. Twin azimuthing thrusters aft and twin bow thrusters forward will provide excellent manoeuvrability and dynamic positioning capability.

As the LNG fuelling sector evolves it will have to operate while the receiving ship is conducting simultaneous operations. This may be cargo operations or the embarkation of passengers and freight. Such factors must, as far as possible, be addressed at the design stage to mitigate risk and ensure maximum operational flexibility. New access challenges must also be addressed to allow fuel transfer between many different types of LNG fuelled vessel. Maintaining schedule will be critical to many customers, so fuel transfer rates can be adjusted to match the capability and requirements of the receiving vessel.

NA: Where are you in the design process?

AC: We are presently in the detailed design stage with HMD and are nearing maturity with tank testing complete. Plan approval is progressing and we are preparing for steel cutting in the next month or so. Cargo tank construction is already underway and the GSV is scheduled for delivery in late summer 2018.

NA: How has the design changed and developed since conception?

AC: The design has certainly changed from its initial conception following the influence of specific project requirements and the demands of potential customers.

Originally, the GSV was of traditional small gas carrier form, with aft accommodation and type C tanks under a trunk deck similar to a semi-pressurised Ethylene Carrier. It was intended for the Black Sea/Danube project mentioned earlier and had to comply with a number of physical restrictions:

1. Pure Gas burning, no liquid fuel onboard except for emergency purposes
2. Environmentally friendly – as mentioned, zero methane emissions during LNG transfer
3. Capable of deep sea navigation (Mediterranean and Black Sea winter conditions) as well as river and canal systems, i.e. shallow draught

Some canal locks and potential ports placed constraints on the length of the GSV, which caused an issue with forward visibility over the cargo tanks to meet SOLAS requirements. This was exacerbated by an increase in capacity from 5,000m^3 to 6,000m^3 and then to 7,500m^3. The solution was to place the accommodation forward, which also provided other benefits. With a better longitudinal balance there was no need for sea water ballast, (some permanent fresh water is used for trim) and this contributed to the environmental credentials required. This arrangement also lent itself to a forward engine room with a power station concept driving twin azimuthing thrusters aft.

In order to take advantage of the commercial benefits of Pilotage and Towage exemptions, enhanced manoeuvring capability was required for the transit of tight places, such as a busy ferry terminal. The standard GSV is DP0 but can easily be upgraded to DP2 as is the case of the vessel presently under construction. It should be noted that our work with existing bunker vessel owners has helped greatly with design improvements for close quarter manoeuvring and for coming alongside and receiving vessels on a regular basis.

An additional innovative design feature, and one that compliments the manoeuvring capability already discussed, is the use of RangeGuard, a product developed by Bernhard Schulte and UK-based DP position measurement technology company Guidance Marine. Originally for the wind farm sector, it is a marine proximity sensor that measures distance to the nearest object. Using radar technology like a car parking sensor, it will enhance the DP0 or DP2 capability to accurately place the GSV alongside tall sided receiving ships with complicated structures, such as the latest generation of cruise vessels.

Another benefit of the power station arrangement is that the main engines are always running during LNG transfer. This enables the GSV in an emergency shutdown (ESD) event to

"All boil off and flash gas generated during fuel transfer is retained onboard the GSV," says Campbell

quick release and vector away from the receiving ship as quickly as necessary.

As the current vessel is not required to enter lock systems, the length overall has been allowed to grow slightly to improve hull efficiency. However, to ensure maximum operational flexibility in future designs, we will strive to reduce the dimensions.

Further changes were seen with Wartsila DF engines replacing the Bergen single fuel lean burn engines originally stipulated. This was mainly because of the increased installed power required in a fixed engine room length. When pure gas burning engines were intended, 'get me home' propulsion would have been provided at up to 4knots using the emergency generator via a forward fully azimuthing pump jet. Pure gas burning engines are still an option for any future customers.

A main component of LNG bunkering is the LNG transfer system. It was originally hoped that a system would be developed by one of the existing technology providers and it would be a complete system purchased. Some manufacturers have certainly done this very well, and we continue to keep an eye on them. Unfortunately, with GSV utilisation a key factor, the range of delivery requirements increased the envelope of operation to include up to a receiving manifold of 21m and down to an adjacent shore side facility or truck. After a review of all the available 'Off the Shelf' equipment, none were found suitable, so we decided to develop our own. Using the expertise of BMT TITRON, Babcock LGE and a number of well-known suppliers in the Offshore STS business, a suitable transfer system was developed that includes all the safety features required by current thinking and legislation.

NA: Can you discuss how the vessel will function in practice?

AC: Our first priority is the safe operation of the GSV, with no injuries, loss of life, damage to property or the environment. As one of the early movers in this new sector, all our resources will be used to train and select competent and well-motivated seafarers to operate the vessel. This will allow our business partners to achieve their objectives using the unique capabilities of the GSV to deliver LNG reliably throughout the year.

NA: You mention that the GSV will fuel a variety of vessel types; does the ship owner/operator already have contracts for this? If so, can you reveal them?

AC: Yes, we are designing the GSV to provide LNG to as many vessel types as possible. This includes the new generation of cruise vessels that may require innovative fendering and other capabilities to come alongside and transfer fuel. As you may know, the first GSV has been time chartered to Nauticor GmbH & Co KG for service in the Baltic region. We have a number of other active projects in progress, but regret we are unable to be more specific for reasons of confidentiality. However, when BSE set out on this course it was not just to build one GSV, so we hope to be able to talk about other projects before long. *NA*

Green tide for Norwegian coast

Narve Mjøs, director of battery services & projects at DNV GL and program director of the Norwegian Green Coastal Program, discusses emissions, alternative fuels and how to incentivise green technologies for shipowners with *The Naval Architect*

Narve Mjøs, DNV GL

Implementation can be the hardest part of any regime change, especially in a market environment where will goes hand in hand with financial reasoning. To date, numerous strategies exist to curtail and cap emissions from ships, but their implementation is still slower than many in the industry would like despite a lot of good will and the 'greenest' of intentions from many shipowners and working groups.

Norway, however, may be a different beast when it comes to addressing environmental issues. Consider the automotive industry in the country, for example. According to Mjøs, more battery cars have been sold in 2017 than traditional gas and diesel in the country thanks to generous, government-funded incentives: free ferry transport, free parking, no taxes for all-electric vehicles and a taxing system based on emissions rather than engine size. Indeed, Norway has been one of Tesla's most important automotive markets.

Given this success, Mjøs is calling for the domestic maritime industry to follow suit; to receive the same legislative treatment and to demonstrate what emissions reductions can be achieved on a national level with a state-sponsored CO_2 fund. This would mimic the format of the already in operation NOx fund: a NOK600 million (US$70 million) per annum resource that subscribers contribute to and take out of as new eco-technologies (focussed on NOx reduction) are implemented. The new Hurtigruten vessels, *Roald Amundsen* and *Fridtjof Nansen*, are proof of the effectiveness of this strategy, having used the fund to become the world's first hybrid-powered explorer ships.

What makes Norway different?

Two years ago, a DNV GL study of all marine traffic in Norwegian waters was carried out based on AIS and satellite data. It revealed that 55% of emissions came from domestic shipping. With such a high proportion of emissions coming locally, and therefore falling under the regulation of the national government, Norway is well-positioned to target emissions from these particular ships and to approach how it might modify its economy for the good of the local (and global) environment.

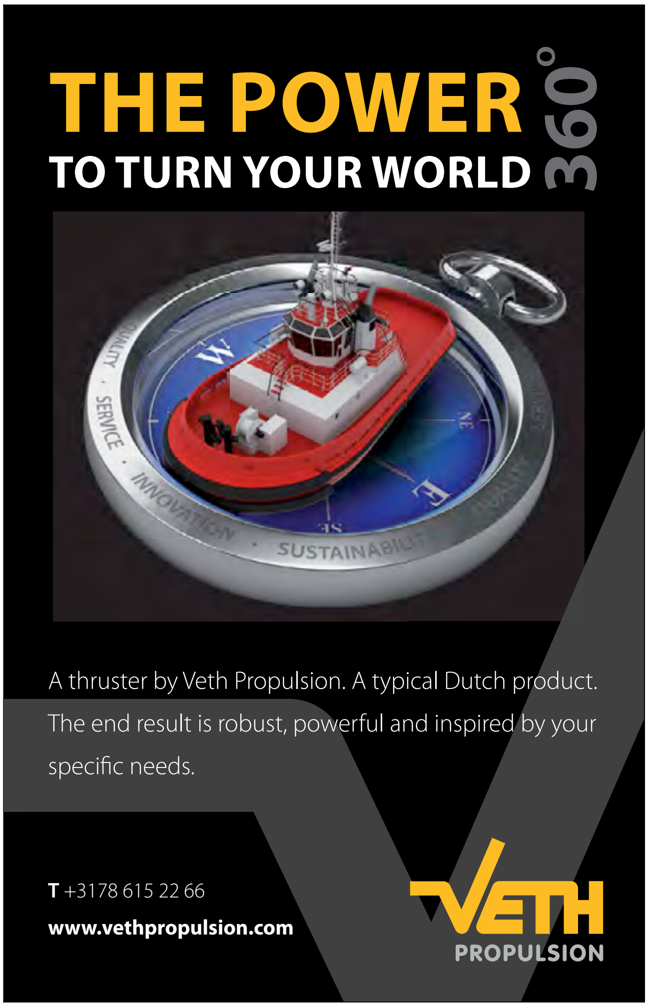
The national government aims to reduce domestic shipping emissions by 50% by 2040, according to Mjøs. However, a substantial level of change is needed to achieve this, he continues. If ships remain as efficient and environmentally friendly as they are today and the economy doesn't change, emissions will rise, rather than fall, by 50%. Of course, this seems an unlikely, worst-case scenario, as technologies will no doubt progress over the 20+ years ahead. But, even taking into account the adoption of 17 breakthrough technologies, including battery hybridisation and Flettner rotors, emissions will still be up by 10%, insists Mjøs. "To be -50% we must use alternative fuels: bio-fuel, LNG, all-electric, and hydrogen."

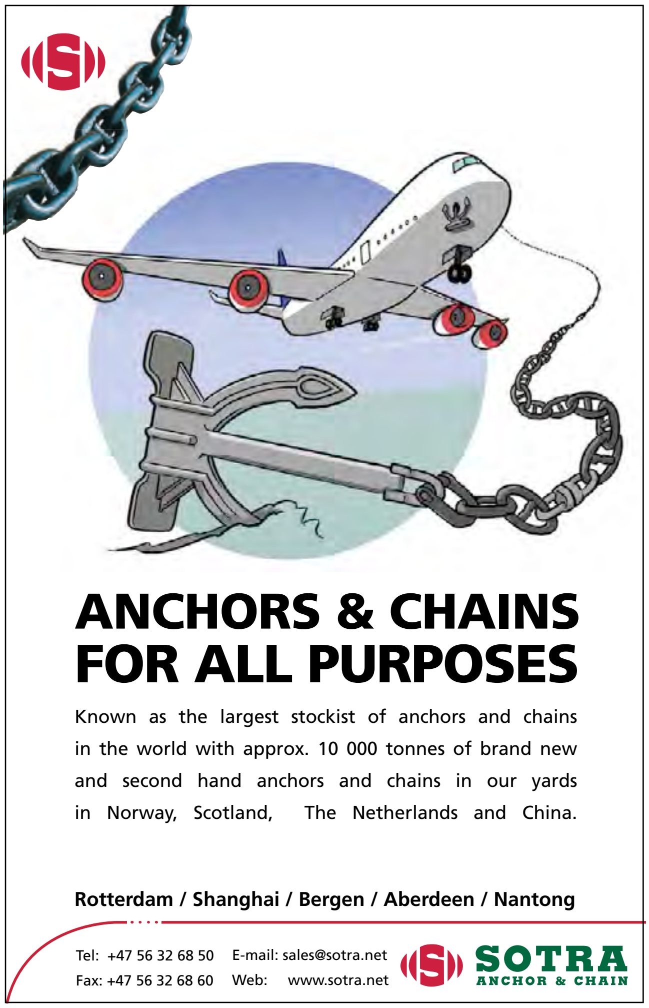
Here enters the Green Coastal Shipping Program (GCSP), a collaboration between government authorities and the private sector. In 2015, the DNV GL-led program began targeting the previously mentioned alternatives, paying specific attention to short-sea maritime transport. In its first phase it evaluated the emission reduction potential for biofuel, battery, LNG and hydrogen-based transportation in Norway, additionally carrying out five initial pilot study projects:

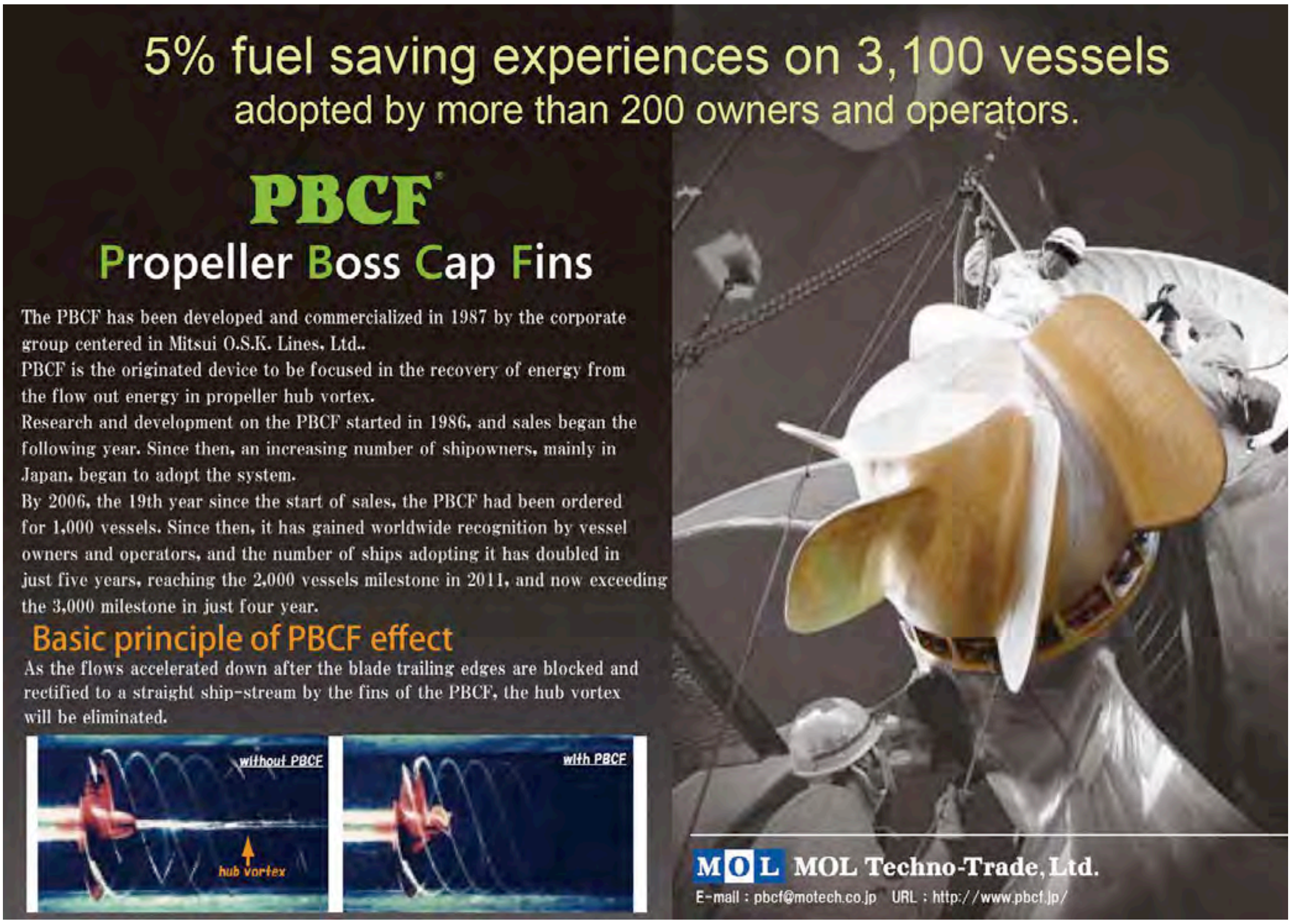
1. A plug-in-hybrid cargo ferry (Norlines)
2. Conversion of a general cargoship to an LNG fuelling vessel (Øytank Bunkerservice/ EGN)
3. A next generation green shuttle tanker (Teekay)
4. A hybrid aquaculture vessel (ABB/Cargo Freighters' Association)
5. Creation of a Green Port (Risavika havn)

Now in its second phase, the program is following up on those projects already carried out, but is also establishing five new pilots:

1. A plug-in hybrid biofuel vessel (Torghatten)
2. An autonomous all-electric cargo feeder (Kongsberg)


THE POWER
TO TURN YOUR WORLD 360°
QUALITY · SERVICE · INNOVATION · SUSTAINABILITY
A thruster by Veth Propulsion. A typical Dutch product. The end result is robust, powerful and inspired by your specific needs.
T +3178 615 22 66
www.vethpropulsion.com
VETH PROPULSION


ANCHORS & CHAINS FOR ALL PURPOSES
Known as the largest stockist of anchors and chains in the world with approx. 10 000 tonnes of brand new and second hand anchors and chains in our yards in Norway, Scotland, The Netherlands and China.
Rotterdam / Shanghai / Bergen / Aberdeen / Nantong
Tel: +47 56 32 68 50 E-mail: sales@sotra.net
Fax: +47 56 32 68 60 Web: www.sotra.net
SOTRA ANCHOR & CHAIN


5% fuel saving experiences on 3,100 vessels
adopted by more than 200 owners and operators.
PBCF®
Propeller Boss Cap Fins
The PBCF has been developed and commercialized in 1987 by the corporate group centered in Mitsui O.S.K. Lines, Ltd..
PBCF is the originated device to be focused in the recovery of energy from the flow out energy in propeller hub vortex.
Research and development on the PBCF started in 1986, and sales began the following year. Since then, an increasing number of shipowners, mainly in Japan, began to adopt the system.
By 2006, the 19th year since the start of sales, the PBCF had been ordered for 1,000 vessels. Since then, it has gained worldwide recognition by vessel owners and operators, and the number of ships adopting it has doubled in just five years, reaching the 2,000 vessels milestone in 2011, and now exceeding the 3,000 milestone in just four year.
Basic principle of PBCF effect
As the flows accelerated down after the blade trailing edges are blocked and rectified to a straight ship-stream by the fins of the PBCF, the hub vortex will be eliminated.
without PBCF
hub vortex
with PBCF
MOL MOL Techno-Trade, Ltd.
E-mail : pbcf@motech.co.jp URL : http://www.pbcf.jp/

3. A hydrogen-powered high speed ship (Flora county)
4. Moving fish transport from road to sea (Cargo Freighters' Assoc.)
5. A low emission fishing vessel (Fiskebåt)

Its overriding aim is to bring all major players in the marine value chain together and to build a complete ecosystem for the development and adoption of green technologies. Mjøs says: "People must lift at the same time and grow together" in order to make this happen. If not, there is a chicken or egg scenario in which a shipowner is compelled to wait for infrastructure while infrastructure waits on the market and development shudders to a halt. The government must facilitate the whole thing to happen, he insists.

"The biggest challenge [for meeting the emissions targets laid out] is that the markets for green technology are not working properly; there must be incentives for shipowners," says Mjøs. However, GCSP is having success in gaining commitments from its participants, which have increased in number from 18 to 35. These commitments mean that those involved in any of the projects have an obligation to adopt successful studies, and thereby push and promote the development of the technologies and designs established.

Phase two of the program aims to address issues of wider adoption, focusing on business cases of key stake holders, executing policy related activities, performing barrier studies, defining incentives and instruments for key business cases and segments, and calculating business and socio-economic arguments for the uptake of green technologies in the local maritime industry.

"In the future, most ships will become plug-in hybrid if the Norwegian authorities show the way by facilitating competitive net tariffs," says Mjøs. "Otherwise it may lead to environmental projects not being undertaken and that shore investments are not being utilised to charge, or to [provide] shore power." In other words, he concludes: "To get an effective implementation of the use of shorepower and a fast market penetration of plug-in hybrid ships, we need a national coordinated strategy."

Where next?

A large number of ferry connections are up for renewal in the next four to five years. This offers a series of opportunities to make environmentally-centred design decisions that can help to realise the 40% reduction in emissions. The national parliament is supportive, according to Mjøs, but it remains to be seen if the problem of incentives (as mentioned above) will be addressed. For Mjøs' part, he expects an "explosion of electrification of ferry connections" and predicts that 2/3 of the public ferry connections will have low or zero emissions by 2030.

Ship charging capabilities will also have to develop if this is to be the case. And Mjøs reveals that work is ongoing to produce a five minute charging solution for a vessel that can carry 120 cars and 360 passengers.

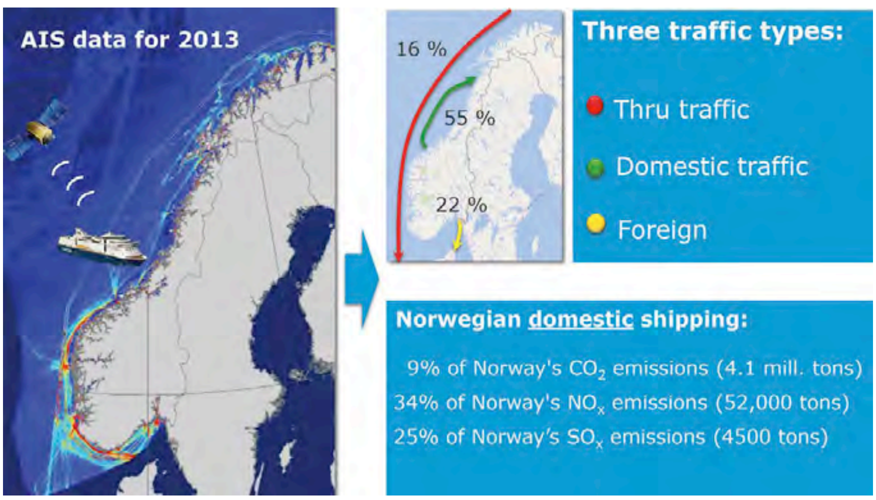
In terms of newbuilds pushing the alternative fuel boundaries in Norway, Color Line recently announced its development of the biggest plug-in hybrid ship in the world, which will be built by Ulstein Verft. The new 160m-long ferry will carry up to 500 cars and 2,000 passengers as it navigates the Sandefjord – Strömstad route between Norway and Sweden, utilising shore power facilities at the Norwegian port it calls at as well as some power regeneration from onboard generators. Most significantly, it is to be equipped with (what will be) the world's largest marine battery at 4MW/h, which will allow it to run emission-free for up to 30 minutes as it travels into and out of Sandefjord harbour.

However, Color Line's ferry is unlikely to hold on to its electric crown long, as Jens Lassen, SVP of newbuilding and projects at Hurtigruten, has already announced that Fridtjof Nansen will be upgraded to feature a similar 4MW battery, more than doubling the 1.2MW battery provision the first in series ship *Roald Amundsen* will include.

With battery prices dropping and energy densities increasing, the uptake of batteries has been much faster than LNG as a fuel. From information delivered at the Maritime Battery Forum, more than 90 ships in operation or under construction feature battery power solutions. The number of LNG ships may be larger at approaching 200 ships, but considering the timeline of development the "explosion of electrification" Mjøs anticipates may soon be on its way – LNG ships have been discussed and developed for 17 years while Li-ion batteries in shipping have only been on the move for three to four years, according to Mjøs.

The Norwegian maritime industry is clearly keen to be at the centre of a wider green maritime economy. Mjøs says many of the companies based in the country are promoting internal projects and subsequent knowledge of abatement solutions to other nations with substantial environmental drivers, such as China. "The Norwegian coast is to be an incubator for the development and export of environmental technologies and green transportation services," concludes Mjøs. In this way, Norway's drive to deliver specialist insight on green projects is promoting a more sustainable maritime economy, both at home and abroad. "If you plan to go green, check Norway", Mjøs finishes. *NA*

A breakdown of shipping in Norway and its domestic shipping emissions



Ferries need support

Mike Corrigan, former president and CEO of Canada's BC Ferries - one of the world's largest ferry operators – shares a compelling priority in his new role as head of global trade association Interferry

One of my main roles on becoming Interferry CEO is to ensure that the industry's voice is well represented to politicians and regulators. I took up the post only in April but, after spending the previous 14 years with BC Ferries, I already fully understood the crucial importance of this mission.

It puzzles and concerns me that those in the corridors of power often treat ferries as an afterthought compared with other shipping sectors and in contrast to their evident support for road and rail infrastructure. I maintain that ferry services are at least as important as these overland counterparts and therefore deserve a level playing field.

I had an opportunity to make this case shortly before joining Interferry. In February the association hosted a reception on the opening day of European Shipping Week in Brussels. I addressed a wide audience including EU regulators, member state representatives, operators and port authorities, advocating greater European Union involvement and investment in the ferry sector. In particular, I questioned why only 3% of total European transport funding is devoted to ferries despite the sector's immense contribution to Europe's economic and environmentally-friendly development. Bearing in mind the tide of policy calls for the modal shift of goods from road to sea, I stressed that ferries offer huge potential to reduce both motorway congestion and harmful emissions.

I also noted that there is overwhelming evidence of growing demand for our services. The latest available statistics show that, in 2015, European ferries carried 34.3 million trailers, 157.4 million cars and 816 million passengers – representing respective increases of 45%, 40% and 60% in 10 years. Vast investment by ferry operators will be needed to keep pace with this demand – and for that to happen, they need to feel confident in and encouraged by the political and regulatory climate.

Mike Corrigan, CEO of Interferry

Time will tell if our argument hit the mark. I have to be hopeful because the reception was preceded by a short-sea shipping seminar organised in conjunction with a formidable supporting cast – the shipowners' associations of The Netherlands, France, Greece, Sweden, Spain and Croatia. Focusing on the economic and environmental actions required to boost short-sea provision, speakers included Sandro Santamato, maritime and logistics head at the European Commission transport directorate; Stena Line CEO Niclas Martensson; Mark Frequin, director-general of transport at the Netherlands ministry of infrastructure & the environment; and Motorways of the Sea coordinator Brian Simpson.

The biennial European Shipping Week was specifically conceived as a platform for EU policy makers to engage with shipowners and other stakeholders. Interferry is among leading shipping organisations on the steering group that oversees the event, underlining our commitment to foster mutually beneficial relations between the industry and its overlords.

This quest has become especially urgent in an era of ever-increasing technical challenges arising from proposed safety and environmental regulations that potentially threaten the financial viability of ferry operations. Since its relatively modest networking origins in the US in 1976, Interferry has seen membership grow to more than 200 operators and suppliers in 35 countries and has emerged as a major force for action on the political and regulatory stage, winning consultative status at the IMO in 2003 and establishing an office for IMO and European affairs in Brussels in 2012.

In several recent IMO interventions, we have fought for sector-specific amendments to proposals more suited to deepsea vessels than to the distinct design and operational requirements of ferries. A prime example came last November when the 97th session of the Maritime Safety Committee (MSC97) finally backed our long-running campaign to look again at damage stability for passenger ships, an issue stemming from the 1994 *Estonia* disaster in the Baltic Sea, which claimed more than 850 lives. The incident prompted the EU to unilaterally impose enhanced structural requirements under the Stockholm Agreement, which was followed by 15 years of research projects aimed at SOLAS harmonisation.

The ferry industry widely went along with this process until the final project unexpectedly signalled a dramatic increase in deck sub-division under the Index R theoretical measure of damage survivability – which implied a massive impingement on roll-on, roll-off vehicle deck procedures. Interferry began to argue that a balance of improved technology and accident prevention measures would be more fruitful than trying to build the unsinkable ship, adding that the suggested subdivision level was too high for smaller passenger ships. This was staunchly opposed by the EU bloc in previous representations and Index R was given the green light at MSC 96 last May.

However, at MSC 97, Interferry joined a submission by Japan, China, Indonesia, Thailand, Malaysia and the Philippines suggesting a more moderate solution for ships certified for less than 2,000 passengers. The idea was still largely opposed by the EU lobby but found unprecedented support from non-EU nations. The MSC chairman then deferred the issue until this June's meeting, meanwhile asking stakeholders to meet informally to determine an appropriate compromise for typically-sized ro-pax vessels. Representatives from Interferry, Japan and the EU have duly met under US coordination to start this work.

Interferry's influence is also highly evident on environmental issues. Last October, the 70th session of the IMO's Marine Environment Protection Committee (MEPC) sanctioned ferry stakeholders to pursue more workable solutions on two of our biggest concerns, the Energy Efficiency Design Index (EEDI) and the Ballast Water Management Convention (BWMC).

Back in 2012 we initially thought that the outcome of the EEDI debate recognised the ferry sector's diversity, but following implementation last year we realised that the calculation was amiss when shipowners and designers reported that new and highly efficient designs scored badly in what amounts to a largely methodological framework. Acknowledging that the problem requires urgent resolution if much-needed newbuilding programmes are to continue, MEPC 70 accepted our call that reference lines for ro-ro and ro-pax vessels should be revised – an argument backed by BIMCO, the International Chamber of Shipping and numerous flag administrations. We are now cooperating to produce recommendations before this May's MEPC 71 deadline for final adjustments.

On the BWMC, which comes into force in September after a 13-year process, Interferry has always insisted that the transfer of invasive species between continents has no relevance on short-sea operations. Together with Denmark, we have lobbied for an 'exemptions' approach allowing coastal states to rule that expensive investment in BWM equipment is not necessary for ships operating exclusively within a limited geographical area. At MEPC 70, our joint presentation of the Same Risk Area (SRA) concept gained wide support and we will now be submitting BWMC/SRA harmonised amendments to MEPC 71 in May.

Much investment in time and money lies ahead on these and many other issues – which I hope explains why we think it is only reasonable for those in governance to demonstrate greater support for the ferry industry's invaluable contribution to society. *NA*

Damage stability update

Keith Hutchinson of Babcock Energy and Marine Technology, on Tyneside in the United Kingdom, reports on discussions and debates at the IMO and elsewhere regarding updates to international damage stability regulations and how they may impact the future design and operation of ro-ro passenger ships

There has been considerable uncertainty in recent years for owners, operators and designers of ro-ro passenger ships. Changes to the current amendments to the International Convention of Safety of Life at Sea 1974, SOLAS, Chapter II-1, will affect the design of new ships with keels laid on or after 1st January 2020, and the degree to which they may be economically compromised in comparison with ships designed to meet the current SOLAS 2009 Regulations is yet to be understood. Understandably, there are significant concerns over the forthcoming regulatory changes, particularly the substantial increase in the R index for smaller ships, the future of the Stockholm Agreement, and how these may combine to influence the economics of any future ro-ro passenger ship fleet constructed on or after 1st January 2020. The following is an attempt to very briefly discuss some of these concerns.

MS Estonia sank on 28 September 1994, with the loss of 989 passengers and crew

Required Subdivision Index, R

At the time of writing of [1] for last year's RINA International Conference on the Design and Construction of Ferries and RO-Pax Vessels held in London, the decision had just been taken at the third Ship Design and Construction (SDC 3) Sub-Committee, held at IMO between the 18th to 22nd January 2016, to finalise the text of a large raft of amendments to SOLAS 2009, Chapter II-1 and submit them for approval to the ninety-sixth meeting of the Maritime Safety Committee (MSC 96) held between 11 and 20 May 2016. Most of these changes were not controversial, having been agreed over several meetings of the Stability, Load Lines and Fishing Vessels (SLF) and SDC Sub-Committees following inter-sessional work by the Subdivision and Damage Stability (SDS) Correspondence Group over the years. However, the final, and perhaps most important, issue involved the proposal to substantially increase the Required Subdivision Index, *R*, which basically governs the overall safety level of passenger ships, both conventional and ro-ro, in terms of damage stability. The 'SDC 3 Proposal line' showing *R* versus *N* (Number of Persons on Board) agreed at SDC 3 and sent to MSC 96 for approval is shown in red in Figure 1. By way of example, for a 1,000 passenger (*N*) ro-ro Passenger ship the *R* would increase from the SOLAS 2009 values ('SOLAS 2009 lines' are shown in black in Figure 1) of between 0.720 and 0.745 (depending on the lifeboat capacity) to 0.837 under this proposal, and for a ship with *N* of 2,000 the *R* would increase from between 0.755 and 0.791 to 0.861.

At MSC 96, the expected approval and recommendation for adoption at MSC 97 of the amendments to Chapter II-1 of SOLAS 2009, including the agreed 'SDC 3 Proposal line' was confirmed, but there were significant objections from Japan to this 'line', particularly for smaller passenger ships – typically defined as those with less than approximately 1,000 persons onboard, N. These concerns were voiced in their paper MSC 96/11/4 and the associated 'MSC 96/11/4 line' is shown in green in Figure 1, for which the R is 0.824 for N of 1,000 and R is 0.853 for N of 2,000. The European Commission (EC) and European Union (EU) member states had anticipated these objections and hence prepared counter-arguments in their paper MSC 96/11/2. MSC 96 noted Japan's objections and the counter-arguments but nonetheless approved the complete set of amendments, including the 'SDC 3 Proposal line'. Hence, all the amendments forwarded for adoption to MSC 97, which convened from 21 to 25 November 2016, recommended an application date of 1 January 2020. The amended version of SOLAS 2009 Chapter II-1 has thereby become known as SOLAS 2020.

At MSC 97, a further significant paper MSC 97/3/7 was submitted by China, Indonesia, Japan, Malaysia, the Philippines, Thailand and Interferry proposing to modify the 'SDC 3 Proposal line' agreed at SDC3. This 'MSC 97/3/7 line' is shown in orange in the Figure and again, by way of comparison, this new proposal suggested that the *R* should be 0.808 for *N* of 1,000 and an *R* of 0.861 for *N* of 2,000. The latter is unchanged from the 'SDC 3 Proposal line', therefore showing that their primary concern was to reduce the R index for ships with fewer persons onboard. After extensive debate, MSC 97 decided to suspend adoption of the draft amendments until MSC 98, scheduled to be held next month at IMO in London between 7 and 16 June 2017. This was carried out to facilitate time for informal discussions and a further compromise – noting that adoption at MSC 98 would still allow the full raft of SOLAS 2020 amendments to enter into force on 1st January 2020.

The debate then shifted to SDC 4 which was held from 13 to 17 February 2017, where informal discussions involving the EC, Japan and the United States of America (acting as 'honest broker') took place between the formal sessions. Here a further compromise was reached, namely the 'SDC 4 Compromise line', which is shown in cyan in Figure 1 and proposes an *R* of 0.816 for *N* of 1,000 and maintaining an *N* of 0.861 for *N* of 2,000. This was subsequently further refined in a joint paper submitted by China, Japan, the Philippines and the USA to MSC 98, MSC 98/3/3, which aims to be a consensus finally acceptable to all. Full details of the latest 'MSC 98/3/3 Consensus line' cannot yet be published as it is still subject to discussion and acceptance at MSC 98.

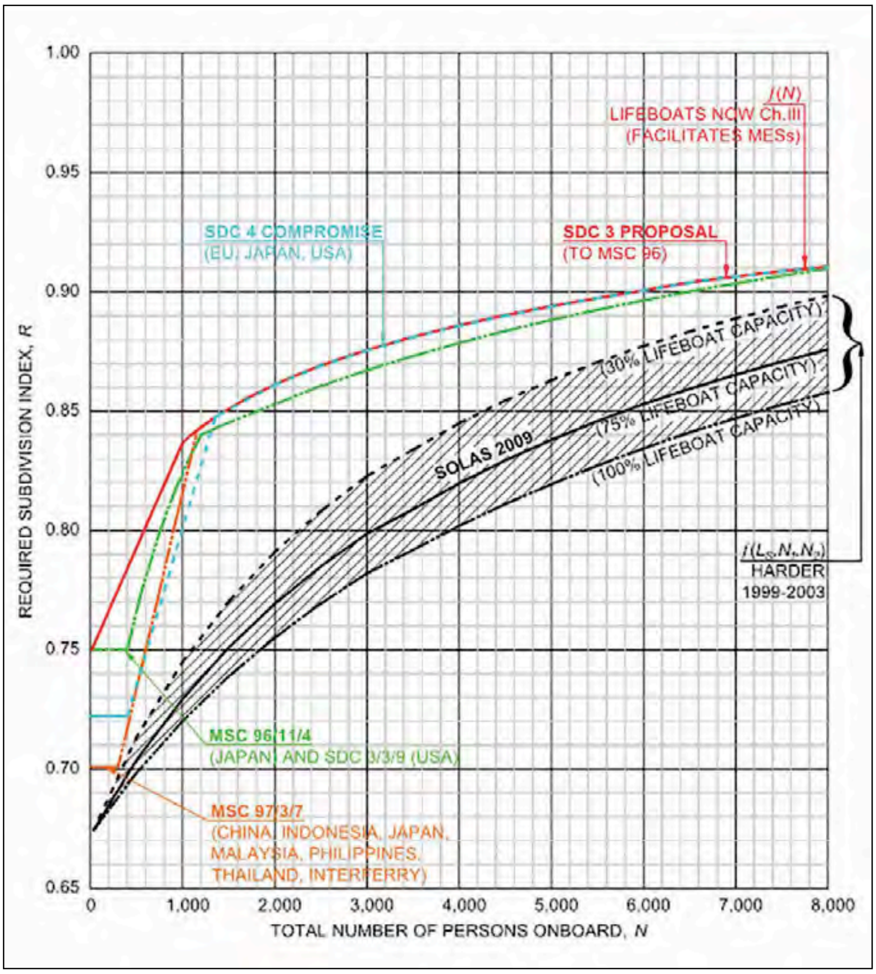


Figure 1: Comparison of current requirements and proposals for revising the Required Subdivision Index *R*

Influence of Lifeboat provision on R

From the above, it can be seen that the current link between lifeboat provision and the *R* index in the SOLAS 2009 Regulations has been removed in the 2020 amendments to SOLAS. It was agreed at IMO that the *R* index should in future be based purely on the number of persons onboard, *N*. Hence, the extent of lifeboat provision in relation to the number of persons carried is now exclusively covered by SOLAS Chapter III, which has not been altered in this respect.

Minor damage

As only a few text amendments have been made regarding minor damage for SOLAS 2020, the general idea that a passenger ship should be able to withstand a limited extent of side damage anywhere along its length will remain in force. Hence, the minor damage regulations (Regulation 8 of SOLAS 2009 Chapter II-1) will continue to apply to SOLAS 2020 ships.

Explanatory Notes

Happily, work on completing the necessary updates to the associated SOLAS 2020 Explanatory Notes was completed at SDC 4 and, subject to final adoption at MSC 98, will enter into force on 1 January 2020 for use in conjunction with the revised SOLAS text. The Explanatory Notes have been expanded considerably and, it is hoped, will be clearer and easier to understand.

Stockholm Agreement

The future of the Stockholm Agreement, namely EC Directive 2003/25/EC as amended, also provides an additional layer of uncertainty, as discussed in Section 6 of [1]. Under the current EC regulatory regime, ro-ro passenger ships constructed on or after 1 January 2009 must comply with both the probabilistic SOLAS 2009 Regulations and the Stockholm Agreement. This is because research indicated that the 2009 Regulations on their own took insufficient account of the dangers of water accumulation on the car deck (WOD) of ro-ro passenger ships.

Expert opinion is still divided as to whether the incoming changes to the s_{final},i factor in SOLAS Chapter II-1/7.2.3 (see sub-Section 4.2 of [1]) and the increase in the *R* index discussed above will 'make up' any possible deficiency in the safety level. In this respect, attention is now turning to a forthcoming EU-funded research project which will investigate this issue in significant depth. The contract duration is 16 months and it is expected that recommendations on a possible review of EC Directive 2003/25/EC as amended, namely the Stockholm Agreement, will be made by the end of 2018.

European domestic ro-ro passenger ships

Currently all EU domestic ro-ro passenger ships operate under EC Directive 2009/45/EC as amended by Directive 2010/36/EU. Under this there are options for complying with either the old SOLAS 90 deterministic damage stability regulations or the current probabilistic SOLAS 2009 damage stability regulations, both in association with the Stockholm Agreement (the amended EC Directive 2003/25/EC)–. At present, the EC's intentions as to whether to rely on the probabilistic 2020 amendments to SOLAS with or without the Stockholm Agreement for new ships constructed on or after 1 January 2020 are unknown; however, it is expected that much will depend on the outcome of the new research project mentioned above.

Recognising that the work completed so far at IMO on amending the SOLAS 2009 Regulations only applies to ro-ro passenger ferries operating on international voyages, it is not unreasonable to assume that there will be pressure from the EU member states to continue with the option to comply with deterministic SOLAS 90 Regulations and the Stockholm Agreement. It should also be noted that for smaller ro-ro passenger ferries it is not unusual, due to their particular design requirements, that the intact stability criteria (especially the severe wind and rolling criteria) will continue to be more onerous than, and hence dominant over, those for damage stability.

Long Lower Holds

There is some concern within the industry that sole reliance on SOLAS 2020 (with no Stockholm Agreement) with its substantially increased R index and a more onerous sfinal,i factor could jeopardise the future of the Long Lower Hold (LLH) designs. These are particularly popular on the longer international ro-ro ferry routes, as they make economical use of cargo space below the bulkhead deck which would otherwise be wasted.

Questions have been raised by operators as to whether the United Kingdom (UK) Long Lower Holds 'equivalence' (see IMO SLS.14/Circ.321) still applies to SOLAS 2009 ships. The fact is that this 'equivalence' only applies to ro-ro passenger ships subject to the Floodable Length requirements of SOLAS 90 and is therefore not applicable to SOLAS 2009 ships, where reliance is placed on these regulations to provide adequate subdivision (albeit in association with the Stockholm Agreement).

> "The current link between lifeboat provision and the R index in the SOLAS 2009 Regulations has been removed in the 2020 amendments to SOLAS"

More generally, the Long Lower Hold issue provides a very clear example of the dangers of relying too heavily on a deterministic criterion relating to extent of side penetration (assumed to be a maximum of fifth of the ship's moulded Breadth, B/5, in SOLAS 90 and earlier) to provide an adequate standard of safety as against relying exclusively on the probabilistic approach as typified by SOLAS 2009 and SOLAS 2020. Research clearly shows that SOLAS 2009 made no provision for the WOD phenomenon which is why the EC decided to retain the Stockholm Agreement. However, the Stockholm Agreement assessment itself relies upon the deterministic B/5 maximum extent of damage whereby it is assumed that damage beyond a longitudinal bulkhead positioned that distance inboard of the side shell is unlikely.

So, at present in Europe there is a mixture of deterministic and probabilistic methods which many feel to be unsatisfactory. Pressure is therefore being applied by some EU member states to remove the Stockholm Agreement for ships constructed after 1 January 2020. The view of the UK is one of extreme caution, based on the findings of several UK-funded research projects conducted prior to 2009. These showed that sole reliance on the probabilistic 2009 amendments to SOLAS could result in the design of ro-ro passenger ships which are vulnerable to loss from water encroachment onto the vehicle deck following quite minor damages in relatively calm waters. However, the UK will contribute to the discussions following completion of the latest EU research project discussed above and will obviously be bound by any collective decision resulting therefrom.

Some research is being undertaken to study the effect of the 2020 amendments to SOLAS on ro-ro design, but whether economically viable Long Lower Hold designs will be feasible after 2020 remains unclear for the moment.

Summary

Considering [1] and this article, the forthcoming SOLAS 2020 passenger ship damage stability regulations have been fully updated regarding ro-ro passenger ships apart from the status of the *R* index. Subject to the deliberations at MSC 98 next month, *The Naval Architect*'s September edition will bid to inform readers of the major changes incorporated within the SOLAS 2020 amendments more comprehensively. *NA*

Disclaimer

The views expressed in this article are those of the author and do not necessarily represent those of the organisations with which he is affiliated or the professional institutions of which he is a member.

Reference

1. HUTCHINSON, K.W. and SCOTT, A.L. 'Passenger Ro-Ro Ferry Damage Stability: Status and Development of International Regulations', International Conference on the Design and Construction of Ferries and Ro-Pax Vessels, The Royal Institution of Naval Architects, London, United Kingdom, 25th and 26th May 2016. ISBN: 978-1-909024-54-0

A user's guide to Shipping 4.0

Smart shipping has become inextricably tied to the notion of a fourth revolution in ship technology, but what does this mean exactly? SINTEF Ocean's Ørnulf Jan Rødseth explains

Shipping has experienced three technological revolutions in parallel with land industry. The first occurred around 1800 with the introduction of mechanized power and particularly steam engines that could provide rotational power and the earliest sea-going ships started to appear from around 1810.

The second industrial revolution took place 100 years later with the introduction of mass production, electric power and the internal combustion engine (i.e. diesel), which allowed ships to operate more efficiently, both in terms of overall power efficiency and weight of fuel, as well as in much fewer crew needed to service the engine.

Third was the introduction of computerized control systems around 1970. This allowed all important engine control functions to be operated from the bridge and enabled a much higher degree of automation with significant lower complexity in wiring and control system construction. The shipping sector was very fast to adopt this and the first computerized control system on sea was on board the M/S *Taimyr*, launched in 1969.

Now we are witnessing a fourth revolution based on the so-called 'Industry 4.0' and incorporating the Internet of Things, Cyber Physical Systems, Big Data and other technologies. As with those that preceded it, 'Shipping 4.0' will have a profound effect on shipping operations and on how the business will be put together. The growing environmental focus on energy efficiency and reduced emissions is expected to amplify the uptake of the new technology.

Shipping 4.0 is mainly characterised by a huge increase in available digital information, but also by new service and operation concepts made possible with better connectivity between ship and shore. Examples are already emerging in e-navigation, third party analytics and administrative shore services and amendments to the IMO FAL convention will require electronic port clearance of ships from 2019 and a growing focus on cyber security at IMO and elsewhere. The eventual deployment of autonomous ships, can be seen as the culmination of Shipping 4.0.

Shipping 4.0: covers a wide range of applications

Components of Shipping 4.0

There is no general agreement of what Industry 4.0 or Shipping 4.0 means or contains, but an attempt to highlight the most important technologies can be seen above.

Cyber Security: Ships and shore operations will increasingly become dependent on secure connectivity and the correctness of transferred data. This has been recognised by most organisations active in the maritime domain. Apart from the communication infrastructure itself, cyber security is perhaps the most important component of the successful digitalisation of shipping.

Open System Integration: The open and integrated access to data on board the ship is critical for Shipping 4.0. This applies to Internet of Services, cyber-physical systems as well as real-time optimisations and other forms of decision support. The ability to add new support tools on board the ship and on shore, as easily as possible, is crucial to the effective implementation of Shipping 4.0.

This means that one needs an open integration framework on the ship that covers all important ship functions and all layers of the on-board data networks as well as data format specifications.

The integration problem is most pronounced on the process layer, where the different main ship control functions are located, e.g. navigation (INS – Integrated Navigation System and

Electronic Chart Display and Information System – ECDIS), engine automation, cargo control, fire and safety.

An important obstacle is that the individual networks normally are isolated and have limited connectivity to each other. If there is connectivity at all, this will typically be via special purpose firewalls or gateways. The firewalls and gateways will also reduce connectivity to whatever is pre-programmed into the respective gateways.

Another related obstacle is the use of many specialised and normally proprietary communication protocols in the different ship systems. This makes it difficult to connect third party equipment to any of the networks and get full access to all the data it can provide.

The open integration should also apply to connectivity between ship and shore. In this case, one can probably rely on reuse of standards from the Internet domain, although adjusted for the lower quality of service that ship communication currently suffers from.

The Internet Of Things At Sea: The Internet of Things (IoT) is an integral part of Industry 4.0 and necessary for the realisation of Cyber-Physical Systems and Internet of Services. IoT on ships is generally more complicated than on land; ships can be large and the use of steel as construction material makes general ship-wide wireless connections more difficult than on land. The weather-exposed external sensors and actuators also require special measures for being securely connected to the ship data networks.

International shipping makes use of a variety of free and internationally regulated data communication systems, typically based on medium or very high frequency digital data links with limited bandwidth. AIS (Automatic Identification System) is the most common example of this. The dependence on generally low capacity and long latency satellite communication when at high seas also makes connectivity to the general internet more challenging than on land.

It is clear that a conventional centralised approach, where high-level application platforms control the whole information flow, is not feasible on ships. However, we still want to make use of mainstream IoT architectures like the ones developed by the Institute of Electrical and Electronics Engineers or the European Telecommunications Standards Institute. To fit the use at sea, these architectures have to allow more efficient use of both intelligence and provisioning of services at the edge networks, as well as include adaptive and dynamic collaborations between application programs.

Cyber-Physical Systems (CPS): A ship is something like a small, self-sufficient village, with systems to support navigation, energy production, life-support and so on. Each of these systems consist of mechanical components like engines, pumps and valves that are integrated, monitored and controlled by one or more computers. The integration of computers with physical components is a CPS. The first CPS are already in place on ships: Many new engines and other complex systems have embedded microcontrollers with sensors and actuators that can monitor, control and adapt physical systems to changing operational conditions or demands. The computers will collect information that can be used in diagnostics of the physical systems to better plan maintenance or repairs as well as being invaluable for the manufacturer or user to assess the performance of the equipment.

Data Analytics: is already playing a role in common applications such as traffic analysis with AIS data (Automatic Identification System) or ship performance analysis based on engine, navigation and environment data. There are, however, important challenges in using data from on-board systems. One is the aforementioned issues with connectivity but another is the various data quality issues that apply to the data that is available. This means that special methods may have to be employed to extract reliable information from the data. Many ship systems are also highly non-linear and clustered data analysis may be necessary. Another problem is the limited bandwidth and relatively costly transfers of data via satellite.

Augmented reality: A significant number of ship accidents can be attributed to human error and while the wealth of information made available to the mariner through e-navigation services should make their lives easier, fatigue, boredom and badly designed bridge systems may actually increase the risks. In recent years there has been increased focus on developing more intuitive, immersive formats for chart information and sensor data that can empower seafarers to work more safely and efficiently. Various forms of augmented reality, e.g. in the form of head up displays or even virtual reality goggles have been proposed and are being tested. Augmented reality may also play a role in shore control centres for fully or partly unmanned ships.

The Internet of Ship Services (IoSS): The infrastructure for using the internet as a medium for offering and selling services, such as fuel quality control, performance monitoring and weather routing. These can be either implemented by the ship operator or bought from third party providers. Many shore authorities are considering providing nautical services to the ship as part of the implementation of e-navigation. If one looks at the 16 currently defined "Maritime Service Portfolios", one will find that all can be characterized as IoSS. Shore services directly related to the physical operation of the ship, such as traffic management and nautical monitoring or control services, are classed separately under "robotics and autonomy"

As is the case for IoT, the realisation of IoSS will need to cater for variable quality of communication links. This means that the concept of IoS for ships may have to be implemented somewhat differently from that on shore and might include more use of store and forward type data exchanges and avoiding reliance on high bandwidth and low latency. This does in particular apply to services that are provided by coastal or port states, that may use special purpose, low bandwidth and cost free data connectivity. The developing VHF Data Exchange System (VDES) is one example of the latter.

Simulation and optimisation: This is conventionally employed in the ship design phase, but data used in these processes as well as the tools will also be important in the operational phase. These are hardly new concepts but there is also an increasing focus on operational optimisation based on simulations across the ship's life-cycle. Simulations and optimisation during ship design is also integral to digital descriptions of ships and ship systems, such as DNV-GL's so-called 'digital twin' concept.

Robotics and Autonomy: Increased automation and use of robotics are not only important components of Shipping 4.0 but essential for the implementation of autonomous and unmanned ships. Many routine ship operations such as berthing and passage through locks might be executed more quickly and safely through automation. Robotics, in the form of automated cargo handling, auto-mooring and automatic hook-up to shore power supplies, will support this and are already being deployed. Shore supervision and intervention in nautical operations on sailing ships can be seen as one possible realisation of the Internet of Services at Sea, but in our opinion, it can more usefully be seen as part of the autonomy and robotics technology.

Partly autonomous ships can provide various types of "driver assistance" or decision support systems that improve lookout, voyage efficiency, heavy weather operation, engine performance as well as shore-based monitoring and assistance functions. During deep-sea passages and in reasonable weather it should be fully possible to let the bridge be controlled by partly autonomous systems, with shore personnel on standby to handle the more complex situations, until it becomes necessary to muster one of the crew to take over.

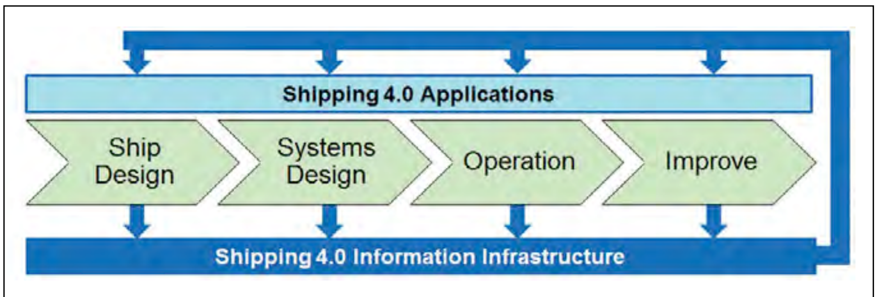
Full autonomy is the culmination of ship automation and increased robotics. The MUNIN project, which ran from 2012-2015, was the first major research in this area and was followed by a number of similar projects from 2013 onwards. Although MUNIN explored the feasibility of a partly unmanned bulk carrier, it became clear that ships will need to be fully unmanned and require an overhaul of existing transport systems to reap the full benefits of the technology.

Non-prioritised components

Some commonly mentioned Industry 4.0 components have not been included for various reasons.

Cloud computing: This is often listed as one of the components of Industry 4.0. However, satellite data connectivity for ships is not normally of high enough quality to utilize cloud computing as it is commonly understood. For ships, one will probably see this technology implemented more as a form of IoSS where specific services rather than the general computing resources are made available. Another type of cloud computing is the so-called 'maritime cloud', a proposed mechanism by which information can be transferred seamlessly between system and over different communication link in the nautical domain. This typically includes

Data management will be essential through the ship's life cycle



ships, shore installations and port services. By its nature, this is more akin to IoT, and the developers of the maritime cloud do stress that it is not related to cloud computing.

Additive manufacturing: As exemplified by 3D printing, additive manufacturing is commonly mentioned as an important component of Industry 4.0. In shipping, one can imagine that this technology could get a position in spare part or consumables production on-board ships and is already being investigated by the US Navy and Maersk.

3D-printing is currently an expensive technique and currently limited to the production of relatively small plastic parts, but metal sintering techniques and larger printers could increase the use of the technology. However, operation of precision printers on-board a ship moving in the waves and with vibrations from large engines and propellers is obviously challenging.

Big Data: This is commonly understood as data sets that cannot easily be handled by conventional data processing hardware and applications. It is often associated by the four 'V's: Volume (amount of data), Variety (high number of sources and types of data), Velocity (speed of new data generation) and Veracity (variable quality and reliability of the data). Well-known examples of big data are medical and diagnostic data from large patient groups, data from search engines and social networks and traffic data from road traffic (Intelligent Transport Systems).

Data analytics will be important in Shipping 4.0, but this data, although large in volume, is not particularly variable in format or quality. Other data related to the ship operation may have high variety and veracity, but rarely high volumes.

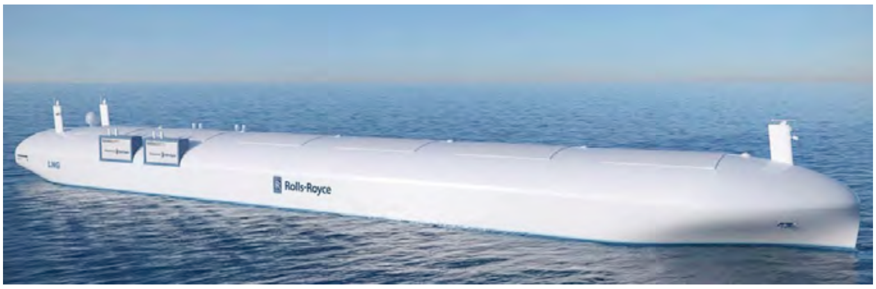
Shipping 4.0 in the Ship Life Cycle

Shipping 4.0 as it has been described here is mainly targeting the operational phase of the ship, but it is obvious that some applications like simulation and optimisation also can be used in design of ships and ship systems (see Figure 4). Communication, monitoring and control technologies like IoT, CPS and open data networks can also be very useful during commissioning of IT-systems and physical equipment on the ship. This can be used effectively during the building and modifications of the ship.

Data collected and analysed during ship operations and after modifications can be used to improve Shipping 4.0 applications used in all phases of the ship's lifecycle as well as improve designs for future ships. The simulation and optimisation tools can reap the most benefit from improvements based on real-life operational measurements and data analysis. This applies both to on-board optimisation tools, e.g. for routing, speed control and ballasting of ship as well as simulations or optimisation tools used during the design of new ships.

The access to information on-board will be critical for realizing many Shipping 4.0 applications as well as the data infrastructure. One prerequisite is open and standard access to the data sources on-board. Today, proprietary solutions and closed interfaces make this more difficult than desired. It would also be very useful if it was possible to compare and benchmark each single ship against other ships of similar type or in similar trade, independent of ownership of ships. This would require some form of third party data base management, e.g. of the type found in BIMCO's Shipping KPI, or direct cooperation between different owners so that data can be exchanged between them.

The possibility to reuse data through the ship's life or between ships raises the issue of data ownership. While most people tend to be of the opinion that the ship owner also owns data generated on-board, the reality is not that simple. One example is advanced data acquisition systems built into new engines and other complex systems, i.e. through the realisation of cyber-physical systems, where the system manufacturer may be the only one able to access or understand all data elements. Another problem is the proprietary data networks that are commonly used on board which effectively hinders the owner in accessing the data flowing on that network.



The MUNIN project was a trailblazer for autonomous shipping

Current activities

E-navigation is defined by the IMO as "the harmonised collection, integration, exchange, presentation and analysis of marine information on-board and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment". E-navigation has defined a number of Maritime Service Portfolios (MSP) that all are examples of IoSS or IoT at Sea applications, typically provided by port and coastal authorities. The strategy development for e-navigation is mostly done in the Maritime Safety Committee (MSC) of IMO while much of the technical work is coordinated by IALA (The International Association of Marine Aids to Navigation and Lighthouse Authorities) and IHO (International Hydrographic Organisation).

The Facilitation Committee (FAL) in IMO as well as MEPC (Maritime Environment Protection Committee) are also working on electronic reporting formats for ships that can be said to be part of Shipping 4.0. These formats will enable the use of automated services on shore for receiving arrival reports and mandatory ship documents in conjunction with port calls.

Another example of an international initiative to increase digitalisation in the maritime area is the EU's e-Maritime in Europe, which aims at extending e-navigation with elements that also focuses more on the commercial issues in shipping, such as cost and efficiency of ship and port operation. This has sometimes been called the maritime variant of the Intelligent Transport System (ITS).

Many commercial parties are highlighting the need for further digitalisation of shipping. This ranges from headlines like the "Connected ship" and "Digital Shipping" to several highly profiled and large projects on autonomous ships. There is also a very high interest in data analytics or Big Data in the maritime businesses.

Maritime technology forecasts from both Lloyd's Register and DNV GL highlight the same developments towards smarter ships, connected ships, autonomous ships and so on. Thus, there is a clear consensus that digitalisation in shipping will continue and that the future will look very similar to what we have outlined as Shipping 4.0.

Need for Standards

Standards are already being developed to support Shipping 4.0. This includes standards for ship data networks and for information transfer between ship and shore. However, developments are relatively slow and much more effort is needed to provide the necessary foundation.

Open standards are perhaps the most important factor to accelerate the development of Shipping 4.0. The shipping business is relatively small with around 80,000 ships in regular international trade. This is a correspondingly small market with very limited room for innovations if the current regime with proprietary interfaces and networks continues. There will of course be innovations from the different manufacturers of systems for use on their networks, but much of the promise of Shipping 4.0 lies in the integration of information from across systems and between ships where, more often than not, control systems are delivered by different manufacturers.

It is probably necessary with a stronger involvement from the ship owners, where they require more openness in system integration and data interfacing. This will come at a cost, but this will be much lower than the gains one can get from better integration of systems and simple access to data for analysis.

Similarly, the implications of data ownership require further investigation. There is a tendency today that some advanced monitoring and control systems supply performance and maintenance related data that is not accessible for the ship owner. This may hinder deployment of Shipping 4.0. *NA*

Ørnulf Jan Rødseth holds a master's degree in electronics engineering from the Norwegian Institute of Technology (now NTNU) in 1983. He has worked with maritime computer and data communication systems since 1990. He is currently a senior scientist at SINTEF Ocean AS in Trondheim, Norway.

This work has in part been supported by the Norwegian Research Council through the projects SESAME Straits and CySiMS.

The melting pot

Negotiating a shared and busy port environment can be difficult at the best of times, but the introduction of autonomous ships will add fresh complexity to port scenarios. A research team from Delft University of Technology, The Netherlands, explores potential methods for safely managing manned and unmanned vessels in port

The port environment is characterised by continuous communication between vessels and traffic control stations, which poses various challenges for autonomous navigation. In response, our research has sought to tackle these challenges with four control levels. These permit the navigation of an autonomous vessel in today's port environment based on whether the ship is underway and the need for VHF-communication.

At this point in time, VHF-communication is paramount in port movements and inter-vessel communication. However, computerised VHF-communication within this context being currently unrealistic, a different way is needed to communicate vessel intentions between manned and unmanned ships.

This article provides an overview of different solutions for autonomous vessel navigation in an environment of manned vessels. Our approach adopts the inter-terminal transport of containers in the port of Rotterdam as a framework for autonomous navigation solutions. However, it is our aim that the reader can use our investigation as a general outline and initial tool for research into autonomous navigation in ports. We expect the control concepts discussed to be relatively independent of a vessel's length. Furthermore we expect the concepts to be applicable to vessels over 100m, however for much larger ships the concepts will require further evaluation as these fell outside of the scope of research.

Approach

Four control levels for navigation were identified: strategic, tactical, critical and super critical. The inputs and outputs for each level were used to identify and evaluate multiple solutions.

1. **Strategic level**: The strategic control level concerns decision making before the autonomous vessel leaves the berth. This level relates to all preliminary planning of the autonomous vessels.
2. **Tactical level**: The tactical control level starts as soon as the autonomous vessel leaves the berth and becomes part of active traffic. In this control level the main goal is to follow the route that has been determined in the strategic level.
3. **Critical level**: The critical control level narrows the tactical decision making down to dealing with the unpredictable behaviour of other vessels. Communication between autonomous and manned vessels is, however, possible.
4. **Super critical level**: We define the super critical level as an extension of the critical level. The autonomous vessel now not only has to deal with unpredictable situations, but also with alien objects within its perimeter with whom, to solve the situation, communicating is deemed impossible.

Various concepts were identified for each of the levels. These concepts transform the inputs of each control level into outputs that will be used in subsequent control levels. It is possible to create concepts that focus solely on one control level; however in practice there are preferable combinations of concepts in different control levels because of similar organisational or technical requirements. This is an important consideration when selecting an all-encompassing navigation system that features solutions for all control levels. Figure 1 illustrates the control levels and their interconnections.

1. Solutions for strategic control

Inputs for the strategic control level are the current position of the autonomous vessel, the destination of the vessel and the corresponding scheduled time of arrival. Solution concepts for this level provide a preliminary route from 'current position' to 'set destination' as well as a corresponding sailing profile for the autonomous vessel. Two concepts were identified.

Liner service scheduling and route planning

A liner service concept has been developed based on a shuttle service between two or more container terminals, with a fixed route. This route is dependent on participating terminal operators. The port authority has the best overview of vessel traffic flows and collects lots of data of ships and their positions. This knowledge of vessel traffic could be used to avoid busy waypoints in the initial route planning, based on statistical traffic density. As a result, involving the port authority in the implementation of an autonomous vessel in a port would be favourable, minimising the impact of the fixed route on non- automated traffic.

Cargo based scheduling and route planning

A cargo based concept has also been evaluated. It uses dynamic route planning to minimise its impact on other traffic inside the port. More specifically, this strategy translates into a route near the right side of the waterway and usage of waypoints as in aviation. The knowledge of the port authority could again be used to avoid busy waypoints in the initial route planning.

2. Solutions for tactical control

For the tactical control level, inputs are the preliminary route and the corresponding sailing profile chosen within the strategic control level with an according ETA. Outputs are continuous iterations of the original route, sailing profile, and ETA, as the autonomous vessel deals with behaviour of other traffic participants, which is predictable.

Following manned ships in platoons

The concept of ship platooning implies the autonomous vessel following manned cargo ships that sail (partly) the same route on a fixed distance to get to the desired destination. All communication about traffic situations is handled by the manned vessel in this scenario so that the autonomous vessel only has to mimic the leading vessel's behaviour. This reduces the number of situations that fall within the critical control level.

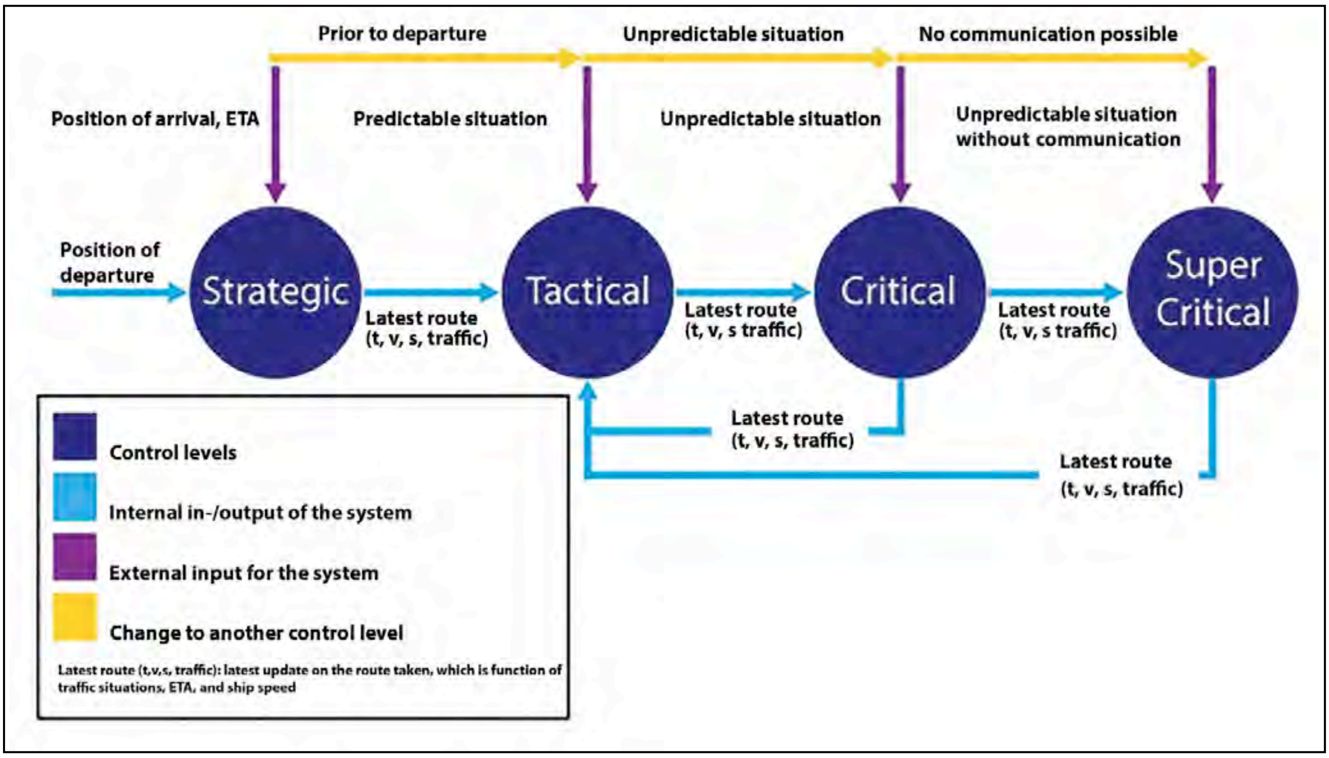
It is important to stress that the leading manned vessel will not be responsible for the unmanned vessels in the platoon. It only provides a 'safe-to-sail' route for the unmanned vessels. Ship platooning requires manned vessels that pass through the area of operation of the autonomous vessel to determine and communicate a preferred route based on waypoints. These routes are then centrally monitored by the shipowner within a shore control centre (SCC). However, involving the port authority for traffic monitoring is preferable.

From an organisational point of view, three main elements are needed for the concept to function. First, an online platform (monitored within the SCC) is needed where captains of manned ships and terminal operators enter ship and route information. Ship routes can subsequently be set by using waypoints and more strictly determined lanes from which captains can only deviate in emergencies or during special manoeuvres (e.g. mooring). This concept works best when it is applied in larger areas of operation with relatively high traffic. To ensure maximal efficiency on longer routes, the third organisational element needed is thorough coordination of current VHF-sectors in the port. In this way, both manned and unmanned vessel predictability can be at its highest.

Within this concept the autonomous vessel can make decisions about the best combination of ships to follow based on the constraint of the initially determined ETA and the available vessel routes. The combination that comes closest to the original ETA will be chosen and communicated with. Captains of manned ships have the last word in approving the platoon with the autonomous ship. This concept requires exact positions and speeds of possible platoon combinations, and could be realised by increasing the Automatic Identification System (AIS) accuracy and refresh rate, as well as further improvement of the possibilities regarding route projection of AIS.

To determine the safe following distance, the autonomous vessel needs information about ship characteristics and cargo hazards. This could be provided by the Harbour Master Management Information System (HaMIS) for the Port of Rotterdam or by similar systems in other large ports. Thorough data integrity and security is needed for the transfer of this data. To mimic movements of the leading vessel, Laser Imaging, Detection and Ranging (LIDAR) sensors could be used to constantly maintain a fixed distance between the autonomous vessel and the leading vessel. Whenever the autonomous vessel is not in a platoon (i.e. between the release and rendezvous points), other tactical solution concepts are required to navigate the vessel to the next platoon. One possibility would be to remotely control the autonomous vessel from the SCC in these instances. Finally we foresee the need for the development of a module onboard the manned ships which would transfer and display all ship and platoon information for the participating captains.

Figure 1: Control levels and interconnections



The European NOVIMAR project is currently examining platooning possibilities and confirms that fully autonomous navigation through dense traffic areas is too big a step, at least for now.

Anticipating traffic situations

The second concept is based on the capability of the autonomous vessel to anticipate traffic situations. This means adapting the sailing profile and route to avoid critical situations (i.e. the need for communication with manned vessels). In order to anticipate traffic situations, two major parties should be involved, the port authority, which already has the general overview of traffic inside the port, and a SCC that also requires the same overview to be able to monitor or control the autonomous vessel remotely.

Different gradations of autonomy can be chosen within this concept, offering variable consequences for technical requirements and the organisation of the SCC. This is visualised in Table 1.

The information about manned vessel positions and behaviour can be communicated to the autonomous vessel by either SCC or the port authority. In the case of local, fully autonomous anticipation, a combination of AIS, LIDAR and stereo cameras is recommended for complete situational awareness. Traffic cameras on shore near harbour entrances would provide better vision for blind spots behind buildings. Prediction of planned traffic participants could (for the port of Rotterdam) be provided by an extension of HaMIS. The range of the route optimisation distance could be set to 2km ahead of the autonomous vessel, based on practical observations. The optimal route is chosen with the original ETA as constraint. Furthermore a safety perimeter, based on ship and cargo characteristics, around autonomous and manned vessels is advised to ensure safe passing of ships. The critical control level will be triggered once the safety perimeter is breached.

Port-wide route optimisation for all vessels

The concept of port-wide route optimisation assumes that routes of all cargo vessels in port are centrally planned based on actual time of departure from berth, destination and ETA. This concept drastically reduces the need for direct communication between vessels in the area of operation.

The central planning system would need to process a substantial amount of information from ships and terminals to determine the optimal routes for all vessels in port. One possibility would be to use the current HaMIS system as a starting point for further development, albeit with an extension for inland vessels. The autonomous vessel would follow the route and sailing profile set by the central planning system to its destination. The captains of the manned ships would also need to follow the set path and speed instructions for their vessels.

3. Solutions for critical control

For the critical control level, the inputs are the current location, path and vessel speed. The ETA is not an input for the critical control level. The critical control level is triggered by unexpected

Degree of autonomy	Role of shore control centre
Remote control	Determines path solution, controls autonomous vessel
Remote decision, local control	Determines path solution, communicates solution
Local decision and control, remote approval	Checks autonomous path solution
Fully autonomous	Monitors autonomous vessel behaviour only

Table 1: Gradations of autonomy and the shore control centre role within the concept of anticipating traffic situations

situations in the surroundings of the autonomous vessel. These need to be identified first, then evaluated and solved. The outputs of the critical control level are an altered path and speed (in response to the situation), and the autonomous vessel's navigation model returns to the tactical control level.

Identification of unexpected situations

A whitelist is a first way to identify unexpected situations. This whitelist contains previously known information about the immediate surroundings of the autonomous vessel. By using different types of sensors, the actual perception of this environment can be compared to the whitelist. If the information does not match, an unexpected situation is identified and the critical control level is triggered. Constant human supervision is the second way to identify such situations. This would translate into continuous camera-based surveillance as in automated industrial processes. Human judgement of possibly critical situations would in this case trigger the critical control level. The third method of identification uses a safety perimeter around the autonomous vessel. The size of this safety perimeter depends on characteristics and status (underway, mooring and anchored at berth) of the autonomous vessel. The critical control level would in this case be triggered by a violation of said safety perimeter by another vessel.

Handling the critical control level

Three ways have been identified to solve critical traffic situations by human intervention from the SCC. A first way is to introduce a remote control handover to an operator. Based on a virtual reality bridge and simulation-like transmission of acoustics and motion senses the operator would be able to solve the situation. In this case, getting the human-machine interaction right is extremely important. A quick selection of waypoints by the SCC is a second way to solve the situation, be it on a much smaller scale than previously discussed within the tactical control level.

After identification of a critical traffic situation, a shore-based operator could use a selection of waypoints to set a new path for the autonomous vessel. Alternate route proposal is the third way by which the critical control level can be handled. In this case, whenever the tactical route planning of the autonomous vessel has failed and the critical control level is triggered, a human operator asks the autonomous vessel for a series of new paths to solve the situation. The operator then selects the optimal path based on his judgement. In any such case, the human operator uses the VHF-infrastructure to communicate about his actions to other traffic participants in the sector.

4. Solutions for super critical control

The super critical control level is triggered when the critical solution model is unable to solve the situation. The inputs are the same as for the critical control level; however, communication with the super critical element is impossible and the control level therefore requires more specialised concepts that do not rely exclusively on externally provided information.

Identification of super critical situations

Super critical situations require sophisticated sensors and control systems on board of the autonomous vessel to identify alien elements in the immediate surroundings. To classify situations like encountering a person or debris in the water or an oil spill as (non-)hazardous, a whitelist could be used again. On the other hand, a blacklist can be used as an alternative. In this case a list of hazardous items and corresponding reactions is used to assess and, in the next stage, solve the situation. A last possibility is again continuous human supervision. This would require extensive concentration and high work load for the operator at any time and is therefore not recommended.

Handling the super critical control level

This control level can be handled in three ways. Either the systems on board the autonomous vessel are fully autonomous. In this case, an autonomous reaction of the vessel is triggered when a super critical situation is encountered. This requires significant advances in artificial intelligence research. The second way is again remote control. This possibility does not differ significantly from the concepts proposed above and will not be further elaborated. A third conceivable concept would be to have an automatic reaction to super critical situations, i.e. a warning to the SCC or other vessels, after which remote control takes over to actually solve the situation.

Authors

Maurits van den Boogaard, Andreas Feys, Mike Overbeek, Joan le Poole, Robert Hekkenberg.

Note

This article is based on the paper "Control concepts for navigation of autonomous ships in ports", which was presented at HIPER 2016. More information on the project, including future developments, how potential stakeholders might be mobilised, and required technical evolutions can be found in the original paper. *NA*

Acoustic performance

A recent condition monitoring study using acoustics emissions suggests it could offer a solution in situations where vibration analysis isn't possible

While vibration monitoring (VM) has long been in use for the purpose of condition monitoring (CM) onboard ships, the technique is not without limitations. VM involves the detection of vibration over a wide range of frequencies. The detected signal can have a strong contribution from high amplitude low frequency sources such as resonances, out of balance and misalignment. Bearing faults tend to produce low amplitude high frequency vibrations, The result is a low signal-to-noise ratio. Relatively complex signal processing and data interpretation is required to identify a machine with faulty bearings from its vibration signature.

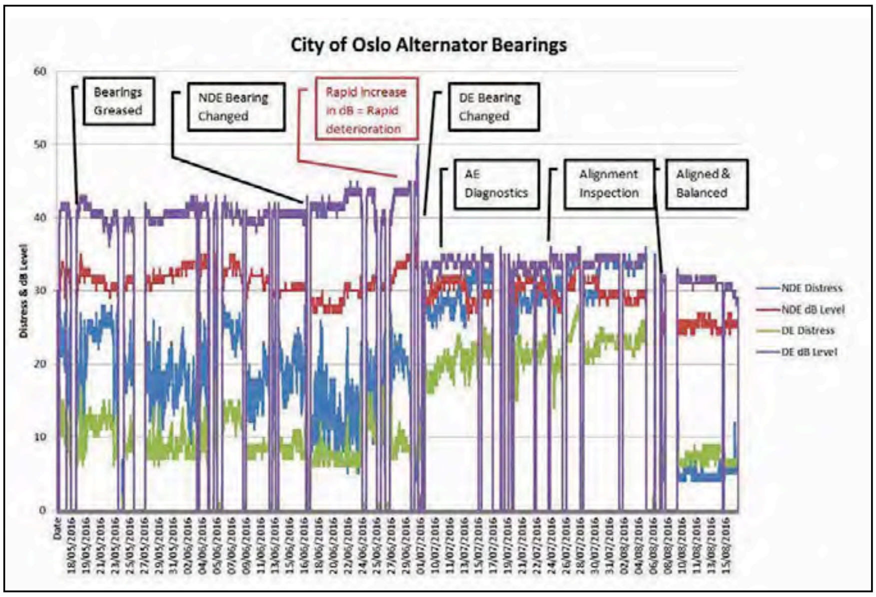
For a number of years, CM and predictive maintenance specialist Parker Kittiwake has been developing a solution to this problem based on monitoring acoustics emissions (AE), a technique based on the detection of high frequency sounds produced by impacts and friction within defective bearings and gears. AE was first developed in the 1960s, initially as a method for detecting crack propagation in materials, but its application to CM is comparatively recent.

AE sensors were mounted on the DE and NDE bearings

Cristiano Garau, Parker Kittiwake's lead application engineer explains: "Our technique is based on detecting these high frequency sounds which are generated by, for example, a defective bearing or lack of lubrication. The sound travels through the structure of the machine and is picked up by our Acoustic Emissions sensor. It is the algorithm that we use to process the sensor output that differentiates us from our competitors."

"We supply the AE technology in a form that is very easy to understand for the end-user. The AE signature is analysed in terms of two parameters: Distress and dB level – Distress is a proprietary parameter that measures transient activity [impacts and frictions] and gives an indication of how smoothly the bearing is running. It is very easy to understand and simple alarm levels can be set. For example, from 0-10 Distress you have a good bearing and from 10-15 you have a bearing that's suspicious. Obviously, you always measure from trending rather than the absolute values and anything over 15 suggests a bearing that may have developed a problem."

City of Oslo data showing the fault detection and correction



The dB level (also expressed on a 0-100 scale) is the mean level of the AE signature and comes into play when more stringent monitoring is required and serves a comparative trending parameter. Typically, doubling the rotational speed increases the dB level by 12dB. A sharp increase of 25dB often indicates that failure is imminent.

Sound events

By moving the detection frequency into the AE range, it is possible to reject the low frequency vibration due to normal running. The result is a dramatic increase in signal to noise ratio. There is a clear difference between the AE signature from a damaged bearing and one in good condition. This has lead to the development of trending parameters that are highly effective yet easy to understand.

"Like VM we use a surface mounted sensor to detect waves generated within the structure of the machine," says Parker Kittiwake technical specialist Neil Randall, who has been heavily involved in refining the AE technique. "But we are detecting at around 100KHz, this is considerably higher than an accelerometer, which generally works up to 10-20KHz. Up at 100KHz what we're actually detecting are the individual impacts that are occurring within the bearing as discrete events. With vibration monitoring what you tend to be doing is monitoring the response of the structure to the repetitive nature of those individual impacts."

"It's a subtle difference but it leads to an important advantage for AE in one particular application area; slowly rotating bearings. Both techniques can be used for monitoring bearing condition at speeds above say, 60rpm. But as you slow things down, with VM you reach the lower end of the accelerometer's detection capability, which tends to be a few hertz. There comes a point at which you will no longer be able to detect the very low frequencies generated if the impacts are being repeated very, very slowly. Because we're monitoring at a high frequency and detect a burst of activity as an individual event it doesn't matter to us how long it takes for the next event to occur, so there's no limit to how slowly you make the rotation."

Case study

Although the testing of AE with slow-rotating machinery has so far been restricted to land-based machinery, Parker Kittiwake has recently published the results of its work on four ro-ro vehicle carriers owned by Gram Car Carriers (GCC): the *Viking Costanza, Hoegh Caribia, City of Oslo* and *Viking Odessa.*

The Japanese-built sister ships, constructed between 2009 and 2010, were each equipped with two 6-cylinder medium speed MAK diesel engines, coupled to the input shafts of a RENK gearbox linked to the propulsion shaft. Each gearbox also had an auxiliary output shaft linked to the main generator, with two auxiliary generators for use in port for cargo loading/unloading. Within their first year of operation, three of the vessels developed catastrophic alternator bearing failures at considerable cost to GCC. In 2015, one of the vessels again suffered a catastrophic bearing failure and checks on the three sister ships revealed they were also developing similar failures.

The precise cause of these failures – whether it was incorrect materials, misalignment issues, alternator bearing design flaws, vibrations or vessel structural problems – was difficult to determine, and even DNV GL, who were consulted, were unable to reach any definitive conclusions.

GCC decided its best recourse was online condition monitoring and, given the particular characteristics of the vessels, opted to try Parker Kittiwake's Alternator Bearing Monitoring System based on AE sensors. Garau explains: "The engine room was too noisy. It had a very complex footprint in terms of vibration to analyse. AE created the opportunity to mask out all those noises and concentrate just on the asset that was failing, i.e. the bearings."

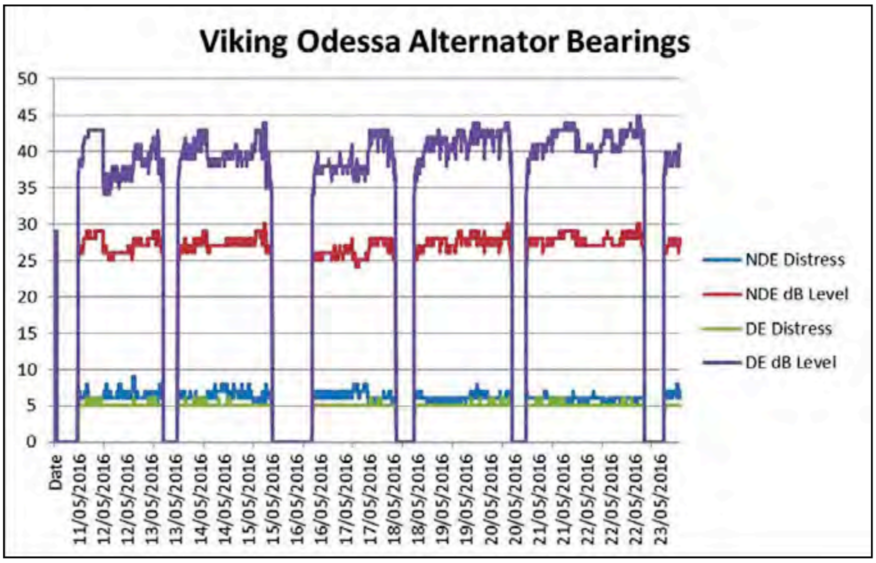
Viking Costanza, which had recently been fitted with a new set of alternator bearings, was chosen as the trial vessel. The Alternator Bearing Monitoring System logs and trends the data streamed by two AE Sigma sensors installed on the drive end (DE) and non-drive end (NDE bearing), as illustrated. The first three months provided valuable data on the stress that normal operational events were putting upon the bearings and the effectiveness of the lubrication, prompting GMM to install the Alternator Bearing Monitoring System on the other three vessels.

Hoegh Caribia and *Viking Odessa* showed similar results, but there was a deviation with *City of Oslo*, which was showing a Distress reading of well over 20dB for NDE, 10dB for the DE, as well as higher dB level readings than the sister ships. Even after the bearings were re-greased, this pattern continued. A month later, GCC decided to change the NDE and the DE bearings a few weeks later. Inspection of the DE bearing revealed significant damage and the new bearing saw a 16dB drop in the dB Level. However, the data indicated that the mechanism causing the damage was still present. A close inspection confirmed that the relative position of the gearbox and alternator had changed. Laser realignment was carried out and the alternator was re balanced using vibration analysis, which finally brought the *City of Oslo*'s Distress readings in line with the other vessels.

The shipping industry has until recently been slow on the uptake of new technology, but Garau praised GCC's forward-thinking approach. "Initially the system was used to identify faulty bearings and manage their replacement. It is now being used on an ongoing basis to ensure continued smooth running of the vessel. The chief engineers have recently added another level to the project and are now using the system to identify operating conditions that put the bearings under excess stress. Their aim is to extend the life of the bearings by minimising the time spent under these conditions."

Take up of vibration analysis has traditionally been restricted by the expertise needed to interpret collected data, but the flexibility of Parker Kittiwake's AE system, and the ability to highlight changes with just two parameters may offer an empowering solution that facilitates a proactive approach to maintenance. Randall says: "Certainly in terms of our sales of portable instruments to general industry, one of the biggest advantages is that it makes condition monitoring accessible to people at the operations level." *NA*

Viking Odessa showed normal Distress levels



A quiet incentive

Ports in British Columbia are incentivising the operation of quieter ships with the help of port fee reductions. Financial stimulus of this kind has the potential to change future designs and is drawing attention from a growing number of vessel segments, according to Eric Baudin, Bureau Veritas

Recognition of the need to control anthropogenic noise pollution is increasing. The EU Commission concluded two projects on the subject matter in 2015, "Achieve quieter oceans by shipping noise footprint reduction" (AQUO) and "Suppression of underwater noise induced by cavitation" (SONIC), publishing a combined set of guidelines by way of conclusion.

These projects were conducted in parallel to find and highlight key commonalities on the effect of ship traffic and other anthropogenic activities on marine life. More recently, an affiliate project of AQUO launched by Ecole Polytechnique, "Racket in the Ocean", commenced in 2016 and concluded earlier this year to bring shipowners, shipbuilders, biologists and regulators together to reinforce past conclusions and discuss where future mitigation measures may be found.

Eric Baudin, head of the onsite measurements section of Bureau Veritas (BV) Marine and Offshore, observes that shipowners are increasingly aware of environmental issues related to underwater noise pollution. Each of the French, Italian and Spanish associations of shipowners were closely following the findings of AQUO, which is "proof they wanted to know more and how in the future they could do something".

"I saw a change in their interest during the AQUO project," says Baudin, who has managed several research projects related to experiments and measurements for BV including SILENV and AQUO, and is now a member of the "Racket in the Ocean" workgroup. "There were many more exchanges between stakeholders and we are still discussing the need to address this topic."

Attracting change

Financial stimulus may help to focus such attention in a meaningful way. In British Columbia, Canada, an economic method to drive noise-friendly ship designs has been established. Both the Port of Vancouver and Prince Rupert Port Authority have implemented port tax reductions for ships certified with quiet notations from BV, RINa or DNV GL. These notations are voluntary, but now offer payback for a shipowner's investment in a ship design that is more environmentally friendly.

Man meets nature. Credit Eric Baudin

To put this in perspective, explains Baudin, say a big containership saves approximately US$4,000 per call to the Port of Vancouver for up to five calls a year, this totals a US$20,000 saving. As a result, shipowners not only gain from being eco-friendly, but also gain financially for their initial design investment, he continues.

The ports have been able to make these reductions thanks to the intense environmental scrutiny of the Canadian government, which has a huge budget to address marine pollution including noise, says Baudin.

Designs

Looking to vessel designs themselves, progress between 2014 and May 2016 was slow for quiet notations, according to Baudin. Most interest in notations such as BV's NR614 URN came from the navy, oceanographic, luxury ship or research vessel segments. However, this started to change at the end of 2016. BV received several requests from cargo ships and passenger ships, indicating that the market for quiet vessels is opening up – perhaps thanks to the combined efforts of more research and more funding options.

Financial strategies like the Port of Vancouver's are sure to have an effect, but it must also be noted that some shipowners want to be ahead in terms of research and development, and actively pursue more advanced designs.

The challenge for these owners is finding the right yard to build their quieter ships. From Baudin's experience, lots of shipyards are yet to possess expertise relating to underwater noise, what may be a new topic for them. As a result, engineering support is gaining traction for design solutions of this type, and second party, perhaps even third party companies are being sought out to help design ships with quiet capabilities.

BV, its specialised partner TDI, S.L. and subsidiary Tecnitas can of course provide services such as those mentioned and Baudin is finding that shipowners are now directly approaching the class society in order to discuss and address noise issues.

When asked if shipowners are therefore also drivers in the bid to control underwater noise, Baudin answered it is difficult to say definitively. But it is clear that an interest in the subject has been sparked and there is some hope that more vessel types will come to feature quiet notations. *NA*

Everything's gone green

The cruise industry's environmental credentials are coming to the fore with the publication of a new survey for the Cruise Lines International Association (CLIA) and new greener ships coming online, writes Sandra Speares

Silver Muse, the new ultra-luxury cruise ship built by Fincantieri for Silversea Cruises, which was delivered at the beginning of April. At 40,700gt and with capacity for 596 passengers on board, *Silver Muse* brings the total Silversea fleet to nine ships. Among the voluntary notations of the ship, is the 'Green Star 3 Design' for units that are designed, built and equipped in order to prevent air and water pollution. Furthermore, the COMF-NOISE A PAX and COMF-NOISE B CREW notations assigned on the basis of noise levels measured on the ship.

Aluminium was used in construction of certain parts of the vessel to contain weight and the ship will run on heavy fuel oil and diesel, although scrubbers will need to be retrofitted at a later date. There are two 1.000 kW 4-blades bow thrusters, and one 1.500 kW 4-blades stern thruster.

It's been a busy time for Fincantieri, with the recent steel cutting ceremony for the first of three new cruiseships the Italian shipbuilder is building for Virgin Voyages. Each ship will be about 110,000gt, 278 m long and 38 m across the beam, with delivery scheduled for 2020, 2021 and 2022 respectively. The ships will have over 1,400 cabins for more than 2,700 passengers and 1,150 crew.

Few details have been revealed about the design of the new ships although they are expected to include some highly innovative ideas and solutions, notably for energy recovery and reducing the overall environmental impact. For example, they will be equipped with an energy production system of approximately 1 MW, which uses the diesel engine's waste heat.

Fincantieri 's orderbook also includes for four new generation cruise ships for Norwegian Cruise Line for about €800m each with one delivery per year from 2022 to 2025, with an option for two more up by 2027. These ships will form the backbone of the future NCL fleet, being about 140,000gt, almost 300 m long, and accommodating 3,300 passengers.

CLIA report

CLIA recently commissioned a new study highlighting developments resulting new environmental legislation. The report found that as of 2016, CLIA member cruise lines have orders in place for at least 13 LNG powered vessels.

Among these is Meyer Werft's first LNG cruise ship, being built for AIDA Cruises. The first in a new series of Helios Class vessels, it is due at the end of 2018 and will be powered by LNG engines made by Caterpillar/MaK. Meyer Werft says that absolute priority has been given to energy efficiency during design, with features including heat recovery, electric motors, LED lighting, automation, optimised underwater paintwork to reduce resistance and weight-optimised material selection

The *Silver Muse*

Royal Caribbean announced plans for its new Icon class series in October last year, which will be powered by LNG and fuel cell technology. The deal was signed with Meyer Turku and the first vessels will be delivered in the second quarters of 2022 and 2024. The Icon ships are expected to run primarily on LNG but will also be able to run on distillate fuel, to accommodate occasional itineraries that call on ports without LNG infrastructure.

CLIA's report reveals there are plans to retrofit exhaust gas cleaning systems on at least 106 vessels. In addition, CLIA member lines plan to add or retrofit at least 18 vessels for shore power. To date, no viable LNG fuel retrofit option has been identified for cruise ships while underway, "although there is some future technical possibility for this while at berth," according to the report.

As it stands, retrofitting cruise ships for LNG is not a viable alternative because of design issues relating to the carriage of LNG in large quantities on board, among other concerns. Nor has there been a great deal of take up of the cold ironing option for cruise ships, given that shoreside power needs to come from a clean source and most port facilities lack the investment to compete with ships' own greener onboard energy supplies.

CLIA members have ordered at least 26 newbuilds with advanced water treatment systems. Based on these numbers, the report estimates that at least 47% of newly built capacity over the next 10 years will be using advanced wastewater treatments.

As far as Baltic Sea practices for wastewater reception facilities are concerned CLIA and HELCOM have indicated that almost 31% of cruise ships voluntarily use port wastewater reception facilities when available.

Wärtsilä meanwhile has recently developed a complete offering for handling dry waste in cruise ships. The new total offering for both 'black' and 'grey' water waste, as well as disposing of dry and food waste has been ordered for one new vessel (and option for a second) to be built by Meyer Werft for British operator Saga Cruises.

Each vessel will be fitted with Wärtsilä's Advanced Wastewater Treatment system, a dry waste disposal system, food waste vacuum system, bio-sludge treatment system and a dry garbage system. The system is in full compliance with IMO Resolution MEPC 227 (64) including Ch. 4.2 nutrient removal (Helcom), MARPOL annex IV Reg. 9.2 and 11.B, as well as USCG discharge standards. *NA*

Air support

Lifeboat ventilation as well as the ever-controversial subjects of drills and release system testing were debated at IMO in March. Sandra Speares reports

Ventilation in ships' lifeboats was a key topic for discussion at the Sub-Committee on Ship Systems and Equipment (SSE) meeting, as was the issue of whether or not lifeboats containing passengers or crew members should be heated or cooled to improve conditions for those obliged to use them.

Inevitably there were differences of opinion among those countries operating in polar waters. Concerns were also raised over the issue of using active ventilation systems in lifeboats when these might fail in perilous conditions.

At SSE 4, the working group on Life-Saving Appliances (LSA) considered methods and criteria for improving the microclimate inside totally enclosed lifeboats. After discussing the methods of ventilation (active versus passive), it was agreed not to exclude passive ventilation, if such passive ventilation will provide the required performance.

According to Kent Mølsted, global rules and regulations manager with VIKING Life-Saving Equipment: "We are quite sceptical about the principle of active ventilation in lifeboats since this method renders evacuees dependent on a running engine and sufficient fuel to stay ventilated. It is not desirable to base the maintenance of a life-supporting microclimate on a single failure-capable system and instead, regulations should aim to secure sufficient passive ventilation in relation to scientifically accepted threshold values."

Some delegations raised the question whether any future amendments would also cover partially enclosed lifeboats and other types of survival craft, but the group agreed to initially focus on totally enclosed lifeboats. "Should new IMO requirements for ventilation be deemed necessary to further the safety of evacuees, we fully support that such regulations be adopted in a manner technically feasible for all types of survival craft," Mølsted said.

Based on a substantial divide in delegate opinions and consensus gaps regarding research and experience data, the group agreed that it is not feasible to reach a conclusion on the matter at this session, and agreed to invite the Sub-Committee to establish a correspondence group to further progress this issue intersessionally. "VIKING is dedicated to contribute to and follow up on this development," Mølsted concluded.

The Bahamas and Japan put forward a paper to the meeting outlining problems noted during the *MOL Comfort* incident involving awkward conditions inside survival craft. Papers presented considered the amount of air changes needed per hour aboard survival craft. Trade association the International Chamber of Shipping (ICS) subscribed to the view that passive ventilation should not be discounted, marine director John Murray said.

> "We are quite sceptical about the principle of active ventilation in lifeboats since this method renders evacuees dependent on a running engine and sufficient fuel to stay ventilated"

"If the manufacturer can come up with a mechanism that does not rely on forced ventilation it would be good. To my mind building a bit of electric kit in a lifeboat which spends its life in a horrific environment isn't going to work when you want it to." Also at issue was whether to cool down the temperature inside the boat, and there were representations by Canada and Norway on the issue because of conditions prevailing in Polar regions which might require lifeboats to be heated. The correspondence group is now to look at all the issues together so as to avoid a proliferation of different guidelines.

One of the arguments was relating to heating leading to seasickness and dehydration resulting from it. The size of lifeboat would also make a difference to the number of air changes. "If the air quality inside the boat was stipulated it would be up to the manufacturer to put something in – passive or powered – that ticks the box," Murray said. Canadian proposals included the fact that in some cases passengers would be in the boat for some time and therefore there might need to be toilet facilities, for example. If that came in on ordinary lifeboats on non-passenger ships, that could cause space problems. Space available for lifeboats onboard existing ships could be limited.

Murray said the ICS had worked closely with both the industry and administrations on the issue of simulated releases of lifeboats. Among other developments he noted a paper issued by Panama during the plenary session proposed separating the drills and testing of freefall lifeboats, which Murrays believes have become excessively interwoven. The idea drew the support of the entire plenary including unusually both North and South Korea. The issue of separating drills from testing was agreed, although detail relating to the testing of hooks was removed subsequently following an intervention from IACS.

Current guidelines going forward now lack guidance on how to test the release mechanism, Murray said, although there is a recognition that the issue needs to be addressed. "Unless the testing is safe, you have still got a problem,"he noted, adding that it may be a subject that the industry lifeboat group will need to return to and could ultimately require some amendments to SOLAS. *NA*

ADVERTISERS' INDEX

If you would like to receive further information on the advertisers' featured within *The Naval Architect* please contact **John Payten, Group Sales Director,** jpayten@rina.org.uk

Client	page	Client	page	Client	page
Aco Marine	53	Liebherr GmbH	45	Roxtec	39
Brunvoll AS	21	Lonza	IBC	Schottel GmbH	4
Cadmatic	11	Man Diesel & Turbo	FC	Seawork Exhibition	25
Class NK	13	Marine Software Limited	19	Sener Ingenieria Sistemas	6
Computational Dynamics	27	Marintec China 2017	31	Sotra Marine	37
CR Ocean Engineering	41	MOL Techno-Trade Ltd	37	Steerprop Oy	35
Faststream Recruitment Ltd.	63	Palfinger Marine GmbH	9	The Mission to Seafarers	63
International Registries Inc.	39	Piening Propeller	15	Veth Propulsion BV	37
Jotun Coatings	BC	Pompe Garbarino SpA	47	Wartsila Finland Oy	IFC
Kawasaki Heavy Industries	23	Rolls-Royce Marine AS	27	Wolfson Unit	29

RINA publications

Books

Please note all prices include postage & packaging

LAMENTABLE INTELLIGENCE FROM THE ADMIRALITY
By Chris Thomas
HMS Vanguard sank in thick fog in Dublin Bay in September 1875 rammed by her sister ship. No lives were lost (except perhaps that of the Captain's dog) but this one event provides valuable insight into naval history of the late nineteenth century. Chris Thomas examines what happened, setting it in the context of naval life, the social and economic situation of officers and ratings. He describes the furore caused by the unjust verdict of the Court Martial, vividly illustrating the joys and trials of the seagoing life in the Victorian era, and the tragic effect on the life of Captain Richard Dawkins and his family.
Price: UK £9.00 EUR £10.00 OVS £12.00
AMAZON PRICE: £12.74

SHIPS AND SHIPBUILDERS: PIONEERS OF SHIP DESIGN AND CONSTRUCTION
By Fred Walker FRINA
Ships and Shipbuilders describes the lives and work of more than 120 great engineers, scientists, shipwrights and naval architects who shaped ship design and shipbuilding world wide. Told chronologically, such well-known names as Anthony Deane, Peter the Great, James Watt, and Isambard Kingdom Brunel share space with lesser known characters like the luckless Frederic Sauvage, a pioneer of screw propulsion who, unable to interest the French navy in his tests in the early 1830s, was bankrupted and landed in debtor's prison. With the inclusion of such names as Ben Lexcen, the Australian yacht designer who developed the controversial winged keel for the 1983 America's Cup, the story is brought right up to date.
Price UK £12.50 EUR £16 OVS £18
AMAZON PRICE: £21.25

THE ROYAL INSTITUTION OF NAVAL ARCHITECTS 1860-2010
Published to commemorate the 150th anniversary of the founding of the Institution, The Royal Institution of Naval Architects 1860-2010 provides a history of the Institution as reflected in the development of the naval architecture profession and the maritime industry over that time. In the book, members give their personal views on the development of their sector of the maritime industry and how it will develop in the future.
Price UK £5.50 EUR £6 OVS £7
NOT ON AMAZON

International Journal of Maritime Engineering (IJME)

2017

Members Part Ref: IJME17 Set Ref: ST17

Part A1	Part A2	Part A3	Part A4	Set
£18	£18	£18	£18	£49

Non-Members Part Ref:IJME17 Set Ref: ST117

Part A1	Part A2	Part A3	Part A4	Set
£25	£25	£25	£25	£82

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)

2017

Members Part Ref: IJSCT17 Set Ref: SS17

Part B1	Part B2	Set
£18	£18	£31

Non-Members Part Ref: IJSCT17 Set Ref: SS117

Part B1	Part B2	Set
£25	£25	£45

IJSCT - is published in June & December. The IJSCT provides a forum for the specialist reporting & discussion on technical & scientific issues associated with research & development of recreational & commercial small craft.

Each month RINA offers up to 70% discount on the normal price of its publications.
Please visit the website at www.rina.org.uk/bookshop-bargains
to see this months specials.

Journals

THE NAVAL ARCHITECT

quarterly publication **OFFSHORE MARINE TECHNOLOGY**
bi-monthly publication **WARSHIP TECHNOLOGY**

Published 10 times a year

- Providing up-to-date technical information on commercial ship design, construction and equipment.
- Regular reports on centres of shipbuilding activity worldwide.
- Comprehensive, technical descriptions of the latest newbuildings.
- News, views, rules & regulations, technology, CAD/CAM, innovations.

2017 Subscription

12 months	Print only†	Digital Only*	Print + Digital
UK	£185	£185	£235
Rest of Europe	£193	£185	£244
Rest of World	£207	£185	£258

†Incudes p+p
*Inclusive of VAT

SHIP & BOAT INTERNATIONAL

Published 6 times a year

- In depth coverage of small craft/small ship design, building & technology.
- Specialist sections include: fast ferries, tugs, salvage & offshore, patrol & paramilitary craft, coastal & inland waterway vessels, pilot boats, propulsion and transmissions.
- Advances in construction materials, electronics, marine equipment.
- Contract news and the latest market developments.

2017 Subscription

12 months	Print only†	Digital Only*	Print + Digital
UK	£136	£136	£166
Rest of Europe	£144	£136	£175
Rest of World	£164	£136	£195

†Incudes p+p
*Inclusive of VAT

SHIPREPAIR & MAINTENANCE

Published Quarterly

- In depth coverage of all aspects of shiprepair and conversion work and comprehensive technical descriptions of major conversion projects.
- Regular regional surveys on the major shiprepair centres.
- Developments in shipboard and shipyard equipment technology.
- Contract news, appointments, industry views, new regulations.

2017 Subscription

12 months	Print only†	Digital Only*	Print + Digital
UK	£63	£63	£83
Rest of Europe	£69	£63	£89
Rest of World	£77	£63	£98

†Incudes p+p
*Inclusive of VAT

RINA publications

Conference Papers

If the CD ROM format is required please add CD after the reference number.

		Non-Members	Members
2017	Design & Construction of Wind Farm Support Vessels	£135	£115
	Smart Ships Ref: SST17	£135	£115
2016	Historic Ships Ref: HIST16	£135	£115
	Energy Efficient Ships Ref: EES16	£135	£115
	Design & Construction of LNG Ships LNG16	£135	£115
	Human Factors Ref: HF16	£135	£115
	Education & Professional Development of Engineers in The Maritime Industry Ref: EDU16	£135	£115
	Warship 2016 Ref: WS16	£135	£115
	Design & Operation of Ferries & Ro-Pax vessels Ref: FRV16	£135	£115
	Innovations in Small Craft Technology Ref: ISCT16	£135	£115
	Wind Support Vessels Ref: WSV16	£135	£115
	Smart Ships Ref: ST16	£135	£115
	Maritime Project Management Ref: MPM16	£135	£115
2015	Education & Professional Development of Engineers in the Maritime Industry 2015 Ref: EDU15	£135	£115
	ICSOT India Ref: ICSOTINDIA15	£135	£115
	ICSOT Indonesia Ref: ICSOTIN15	£135	£115
	Energy Efficient Ship Ref: EEF15	£135	£115
	Pacific 2015 Ref: PACIFIC15	£39	£34
	ICCAS 2015 Ref: ICCAS15	£180	£150
	ICSOT Korea Ref: ICSOTKOR15	£135	£115
	Marine Design Ref: MD15	£135	£115
	Warship 2015: Surface Vessels Ref: WS15	£135	£115
	Mega and Super Yachts Ref: MSY15	£135	£115

PRIVACY

Personal data held by RINA will only be used in connection with RINA activities, and will not be passed to third parties for other use. Full details of RINA's Privacy Policy are available online.

☐ I wish to receive information on technical developments in or related to the maritime industry and on future RINA events. I understand that I may stop receiving such information at any time.

For further information on previous editions please contact the Publications department on:
Tel: +44 (0) 20 7235 4622, Email: publications@rina.org.uk or Website: http://www.rina.org.uk

Payment Details: Payments must be made in pounds sterling to **RINA** by sterling cheque drawn on a UK bank, International Money Order or Credit Card, we accept Visa, Mastercard, or AMEX.

I enclose a cheque for ______________________ payable to RINA.

Please charge my Credit Card No: ______________________

Expiry date: __/__/__ Security code: _____ Signature: ______________________

Print name: ______________________

Name: ______________________

Address: ______________________

Country: ______________________ Postcode: ______________________

Tel: ______________________Fax:______________________Email:______________________

Please allow 30 days for dispatch and delivery. Post to:

The Publications Department, RINA, 8-9 Northumberland Street, London WC2N 5DA, UK.

Tel: +44 (0)20 7235 4622 or **Fax: +44 (0)20 7259 5912.**

ORDER FORM

Please send me the following:

REF NA JUNE 17

REFERENCE	QUANTITY	PRICE
	TOTAL:	

For a publications catalogue please call the Publications Department on
+44 (0)20 7235 4622 e-mail: publications@rina.org.uk or visit our website at http://www.rina.org.uk

May 16 - 18, 2017
IMDEX Asia, international maritime defence exhibition and conference, Singapore
www.imdexasia.com

May 17, 2017
Communication Skills for Engineers Course, London, UK
www.rina.org.uk/Communication_Skills_for_Engineers_Course1

May 17-19, 2017
Torsional Vibration Symposium, Salzburg Congress, Salzburg, Austria
www.torsional-vibration-symposium.com

May 25-27, 2017
Bari-Ship 2017: Imabari Maritime Fair, international exhibition, Imabari City, Japan
www.bariship.com

May 30 – June 1, 2017
Undersea Defence Technology (UDT) 2017, international exhibition & conference, Bremen, Germany
www.udt-global.com

May 30 – June 2, 2017
Nor-Shipping 2017, international exhibition & conference, Oslo, Norway
www.messe.no/en/nor-shipping

June 6-8, 2017
Electric & Hybrid Marine World Expo 2017, Amsterdam, The Netherlands
www.electricandhybridmarineworldexpo.com

June 6-9, 2017
Basic Dry Dock Training Course, London, UK
www.rina.org.uk/Contract_Management_May_2017

June 13-15, 2017
Seawork International, international exhibition, Southampton, UK
www.seawork.com

June 14-15, 2017
Warship 2017: Naval Submarines & Unmanned Underwater Vehicles, international conference, Bath, UK
www.rina.org.uk/Warship2017

June 26-27, 2017
Decommissioning of Offshore & Ship Structures (DOSS 2017), international conference, Glasgow, Scotland
www.asranet.co.uk

June 28 – July 2, 2017
International Maritime Defence Show (IMDS-2017), international exhibition, St. Petersburg, Russia
www.navalshow.ru

September 6-8, 2017
Seatrade Europe, international exhibition, Hamburg, Germany
www.seatrade-europe.com

September 11-13, 2017
BALTEXPO 2017, international exhibition and conferences, Gdańsk, Poland
www.baltexpo.ztw.pl/en

September 12-15, 2017
DSEI, international exhibition, ExCel, London
www.dsei.co.uk

September 13-14, 2017
Influence of EEDI on Ship Design & Operation, international conference, London, UK
www.rina.org.uk/ShipDesign_EEDI

September 19-22, 2017
NEVA 2017, international exhibition, St. Petersburg, Russia
www.transtec-neva.com/home/neva

September 25-27, 2017
Seatrade Offshore Marine & Workboats Middle East, international exhibition, Abu Dhabi National Exhibition Centre, Abu Dhabi, United Arab Emirates
www.seatrademaritimeevents.com/somwme

September 26-28, 2017
International Conference on Computer Applications in Shipbuilding (ICCAS 2017), Singapore
www.rina.org.uk/ICCAS_2017

October 3-5, 2017
Pacific 2017, international exposition, Sydney, Australia
www.pacific2017.com.au/international-maritime-conference

October 11-13, 2017
Contract Management for Ship Construction, Repair and Design Course, London, UK
www.rina.org.uk/Contract_Management_Course_Oct_2017

October 25-26, 2017
Education and Professional Development of Engineers in the Maritime Industry, international conference, London, UK
www.rina.org.uk/EPD_2017

October 25-27, 2017
HSMV 2017 - 11th Symposium on High Speed Marine Vehicles, international conference, Naples, Italy
www.rina.org.uk/HSMV_2017

November 8, 2017
Power and Propulsion Alternatives for Ships, international conference, Rotterdam, The Netherlands
www.rina.org.uk/Alternative-ship-power

November 13-15, 2017
Lightweight Design of Materials and Engineering Structures (LIMAS 2017), international conference, Glasgow, Scotland
www.asranet.co.uk

November 14-16, 2017
METSTRADE, international exhibition, Amsterdam, The Netherlands
www.metstrade.com/mets/exhibition-info/about-the-exhibition

November 22, 2017
President's Invitation Lecture, London, UK
www.rina.org.uk/Presidents_Invitations_Lecture_Dinner_2017

November 29-30, 2017
International Conference on the Design, Construction and Operation of LNG/LPG Vessels, Glasgow, UK
www.rina.org.uk/LNG_LPG2017

December 7-8, 2017
International Conference on Ship & Offshore Technology (ICSOT) India 2017, Kharagpur, India
www.rina.org.uk/ICSOT_India_2017

December 18-20, 2017
Advances in Onshore & Offshore Wind Energy (AdWIND 2017), international conference, Chennai, India
www.adwind2017.com

Marine

Marine Antifouling Technologies

Providing Protection Against Slime and Algae

Omadine®
ANTIMICROBIAL

Lonza's Omadine® Technology used in antifouling paints provides long lasting protection against slime and algae.

Using Lonza's Omadine® Technology Offers:

- Long lasting performance against marine-fouling organisms
- Efficient release of biocides from the coating over the lifetime of the product
- Global regulatory and technical support

Contact us to learn how using Lonza's biocides in marine paints can help increase fuel efficiency and assist in the control of the spread of invasive species.

E: materialsprotection@lonza.com

www.lonza.com