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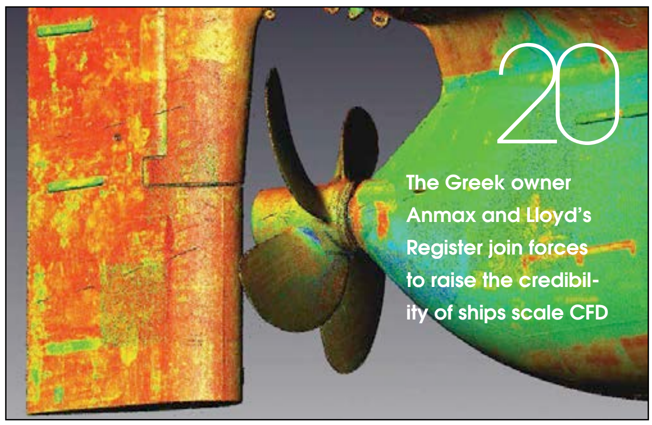

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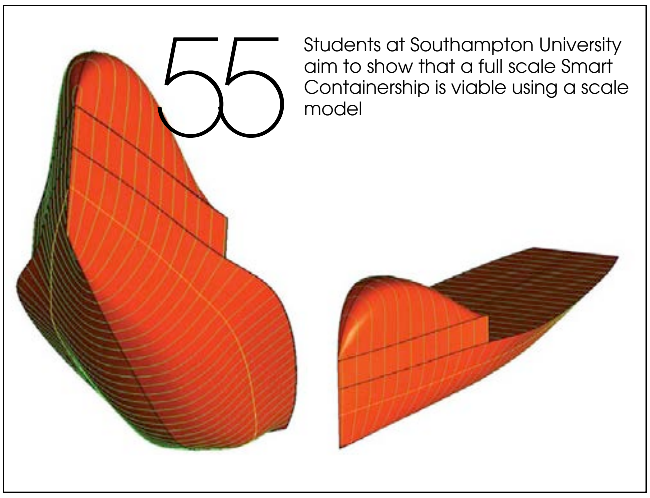

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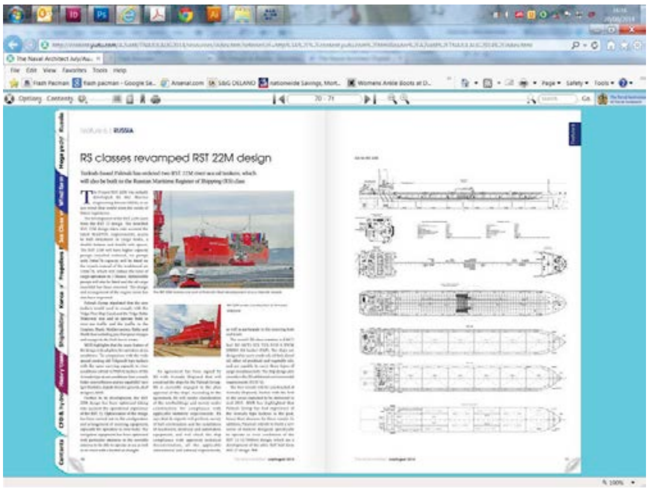

EEDI faces major ro-ro challenge

The EEDI correction factor for ro-ro vessels has come under scrutiny from a number of sources. Has the IMO made an error in its regulation? And if so, is this evidence of a rule making process which has become too complex?

The need for greater regulation in the shipping industry became self-evident following a number of high profile accidents over the last 100 years or so, starting with *Titanic* in 1912. However, making rules has never been as complex as it is today.

Safety issues have been the main focus of these rules, but regulation has been further complicated in the last 20 years by increasing emphasis on the environment and green issues.

Today, as the complexity of regulating shipping is being felt more intensely by operators than ever, the feasibility of the IMO's strategy to limit emissions from the various types of ro-ro vessels is being questioned.

Discussions over the viability of the Energy Efficiency Design Index (EEDI) as it has been devised for ro-ro cargo and car carriers and ro-pax vessels have resurfaced. In this issue, Professor Apostolos D. Papanikolaou and naval architect Aimilia Alisafaki, both of the Ship Design Laboratory, School of Naval Architecture and Marine Engineering, at the National Technical University of Athens, Greece, describe the difficulties surrounding the rules for ro-ro vessels in great detail.

If Papanikolaou and Alisafaki's views are accepted, a major rethink of the rules may be necessary. This could have significant implications for vessel designers and owners alike, as EEDI has the potential to shape the design of future vessels by placing a greater emphasis on reducing vessel emissions. To date, most fuel efficiencies have either been made through reducing speed or through reducing the installed power of new vessels.

However, a reduction in power for ro-ro ships presents major difficulties, as Alberto Portolano, a naval architect employed with the ro-ro ship operator Grimaldi Group, told *The Naval Architect* in the April issue of the magazine. He said: "The second target of 5-10% of EEDI reduction is very strict." Tanker operators and others may find this target easier to achieve, "but with ferries and ro-ro ships it's very difficult to meet the EEDI second phase without reducing the speed [and] that will tremendously affect the service of this kind of vessel."

A passionate debate on the EEDI correction factor for ro-ro ships was seemingly settled in 2013 when MEPC agreed to adopt a solution put forward by the Swedish and German delegates rather than the proposal put forward by Hans Otto Kristensen of the Danish Technical University, which was preferred by the Danish and Japanese delegates.

In the July/August 2013 issue of *The Naval Architect*, Jan Bergholz, a naval architect and a member of the Swedish proposal team, wrote: "In principle, the Swedish concept applies a correction factor based upon ship specific design parameters aiming to normalise the numerator of the EEDI-equation, i.e. the CO_2-burden, to comparable conditions. The correction factor includes the Froude number, resulting in a third order speed power relation, and, moreover, non-dimensional geometric ratios all of which are acknowledged to influence the hydrodynamic performance and hence the energy consumption of a ship."

This solution was supported by a number of industry organisations at the time, including Interferry. However, *The Naval Architect* now understands that Interferry has privately acknowledged that the correction factor based on the Swedish/German proposal cannot work and the group met representatives of the Danish shipowners to discuss the issue in March.

Should the EEDI correction factor for ro-ro ships need amending or rethinking there may well be some pertinent questions asked of the IMO's rule making process. It so happens that in the same issue of *The Naval Architect* that Bergholz wrote his story, the former IMO secretary-general Koji Sekimizu was also quoted from an IMO Symposium held in June 2013, which purported to look beyond compliance and called for a shift from reactive regulation to proactive rule making.

"My aim was to raise issues for the maritime industry," said Sekimizu at the time, adding, the discussion has leaned toward more Goal Based Standards (GBS) and more Risk Based Standards (RBS), but the overriding idea was to "involve everybody in the decision making process".

It now seems that the complexity of the rule making process has significantly increased because more people are involved.This begs a justifiable question, has the process become so complex that regulators are now finding it unmanageable, and is the error in the EEDI correction evidence of this?

In other news, *The Naval Architect* promised readers a story from the UK Hydrographic Office giving their perspective on Smart Shipping. Unfortunately the UKHO was unable to provide the promised story. We would like to apologise to readers for this. *NA*

Acquisitions

Siemens closes CD-adapco deal

Germany's electrical goods manufacturing giant Siemens acquired the global engineering simulation company CD-adapco on 1 April for US$970 million.

The valuation of the company by Siemens reflects the growing influence of Computational Fluid Dynamics (CFD) on manufacturing design in many fields such as car and aeroplane design and also in the maritime industry.

With a workforce of around 1,000, the sale to Siemens values the company at a remarkable US$1 million per worker, but CD-adapco's Starr CCM+ CFD software, along with the company's other products, is clearly expected to build on the near US$200 million profit made in the last financial year.

Klaus Helmrich, member of the managing board of Siemens, said: "As part of its Vision 2020, Siemens is acquiring CD-adapco and sharpening its focus on growth in digital business and expanding its portfolio in the area of industry software. Simulation software is key to enabling customers to bring better products to the market faster and at less cost. With CD-adapco, we're acquiring an established technology leader that will allow us to supplement our world-class industry software portfolio and deliver on our strategy to further expand our digital enterprise portfolio".

Ferries

Stena orders AVIC ferries

AVIC's Finnish subsidiary, Deltamarin Group, has announced its first project to deliver a comprehensive engineering, procurement, construction and management (EPCM) package for Stena's ro-pax ferry newbuilds to be built at AVIC Weihai Shipyard.

"Stena RoRo, a subsidiary of the Swedish ship owner Stena AB, and AVIC International Ship Development (China) Co. Ltd. have signed a contract, subject to board approval, for four vessels including options for another four. These will be one (sic) of the first ro-pax ferries to be built in China for a western owner," said a joint company statement.

Deltamarin, which is 79.57% owned by the Singapore listed AVIC International Marine Holdings, will provide naval architecture services and, what it calls, "comprehensive project management services" to support AVIC SHIP and AVIC Weihai Shipyard in the vessel construction.

These services will include approval design, support in procurement handling, and detailed design. Deltamarin Floating Construction will carry out the construction management in co-operation with AVIC. The project management services also include master planning, procurement of project materials and material management, project information management and site supervision.

The vessel concept was developed by Stena in cooperation with Deltamarin with the new vessels expected to operate on the Swedish owner's North European routes.

"The vessels will have a capacity of more than 3,000 lane meters in a drive-through configuration. They will also accommodate about 1,000 passengers and offer a full range of passenger services. The main engines will be 'gas ready', prepared to be fuelled by either methanol or LNG," said a company statement.

Newbuildings

NYK takes delivery of first JMU boxship

Japanese liner shipping company NYK Line has taken delivery of the first of 10 vessels from the Japan Marine United shipyard following the completion of the vessel's ship trials in February and final fitting out.

Delivered last month, *NYK Blue Jay* is a 14,000TEU containership that will operate in the line's Asia/Europe string. The ships are 364m in length with a width of 50.6m and a load draught of 15.79m, and will be driven by a Wärtsilä 9X82 main engine.

According to Swiss company Winterthur Gas & Diesel (WinGD) "The advanced propulsion concept includes a narrow dimensioned engine room allowing a hull design

Chinese shipyard AVIC Weihai has won a 4+4 order from Swedish owner Stena RoRo which claims these ships will be the first ferries built in China for a western owner

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NYK Line's latest 14,000TEU containerships are designed to compete with larger vessels and are fitted with an electronically controlled dual-rating engine system

with exceptional hydrodynamic efficiency. Another significant part of the operating economy of *NYK Blue Jay* stems from the latest Wärtsilä brand Generation X two-stroke diesel engine, the 9-cylinder Wärtsilä X82 designed by WinGD in Winterthur, Switzerland, and manufactured by Diesel United Ltd. in Japan."

In addition, Rudolf Holtbecker, general manager, business & application development, said: "As we have seen in the recent past, ship owners wish to be able to respond to market conditions by having closer control over the fuel costs of their ships. In recent years this has led to owners operating their ships at lower speeds with engines running below their design ratings. With the [Generation] X engines, the dual-rating option has been introduced to allow ship owners to use their engines either with a low or a high maximum power output, further improving fuel consumption in each operating mode without major modifications."

The dual-rating system is an electronically controlled fuel injection and exhaust valve system that is combined with the engine's turbochargers that have "wide compressor maps". This system developed by WinGD allows the optimisation of the engine for two operating profiles.

Methanol

Dual fuel tankers delivered

Waterfront Shipping, the Vancouver-based chemical tanker operator, a wholly owned subsidiary of the methanol distribution company Methanex, has taken delivery of the first three of seven 50,000dwt dual fuel tankers.

The ships are fitted with MAN B&W ME-LGI 2-stroke dual fuel engines that can run on methanol, fuel oil, marine diesel oil, or gas oil.

Methanex claims that the "ground-breaking ship technology will significantly reduce emissions while giving ship owners a viable, efficient and convenient fuel alternative. With the growing demand for cleaner marine fuel to meet environmental regulations, methanol is a promising alternative fuel for ships that can meet the industry's increasingly stringent emissions regulations."

Ole Grøne, senior vice president, head of marketing and sales, MAN Diesel & Turbo, said: "We developed these 2-stroke engines in response to interest from the shipping world to operate on alternatives to heavy fuel oil and meet increasingly stringent emissions regulations. To hedge the risk of fuel price volatility, the vessels can switch between fuels, and operate cost-effectively."

Although Waterfront Shipping will charter all seven vessels the ownership of the tankers is varied. Two ships were ordered by Westfal-Larsen at Hyundai Mipo Dockyard in South Korea, another two of the vessels are jointly owned by Waterfront Shipping and Marinvest, and three ships will be owned by Mitsui OSK Lines, which also owns a significant share in the Minaminippon Shipbuilding Co where the three MOL ships will be built. The seven vessels will replace older tonnage and expand Waterfront Shipping's fleet.

"Working with our partners to advance new, clean technology is an important and innovative step in the right direction. Investing in methanol-based marine fuel reinforces our commitment to invest in sustainable technology that not only provides environmental benefits but also an economically viable alternative marine fuel. The cost to build new and convert existing vessels to run on methanol is significantly less than alternate fuel conversions," said Jone Hognestad, president, Waterfront Shipping.

Engines

Ditas orders Tier III tankers

Turkish shipowner, Ditas Shipping, has ordered two 158,000m^3 Suezmax crude oil tankers from Hyundai Heavy Industries Ship Building Division (HHI-SBD).

Each vessel will be powered by a single MAN B&W 6G70ME-C9.5 two-stroke main-engine that will include integrated Exhaust Gas Recirculation (EGR) systems, making the vessels IMO Tier III compliant.

MAN said: "While there are already IMO Tier III-compliant vessels with EGR systems in service, the Suezmax newbuildings will be the first vessels with keel-laying after 1 January, 2016 to be officially certified as complying with Tier III emission restrictions within existing North American NOx Emission Control Areas (NECAs) and the United States Caribbean Sea NECA."

EGR is a NOx emissions-control technology that works by recirculating a portion of an engine's exhaust gas back to the engine cylinders. MAN Diesel & Turbo originally developed, designed, and manufactured the first EGR system for a two-stroke marine diesel engine for operation on a container vessel in service in 2010. *NA*

MEPC revisits familiar issues

As the crunch time approaches on whether or not the sulphur cap will be introduced in 2020 or postponed until 2025, April's Marine Environmental Protection Committee (MEPC) discussions centred on the CO_2 data collection system, the Energy Efficiency Design Index (EEDI) and a submission for a determined contribution for reduction of CO_2 emissions, as well as the vexed issue of ballast water technology, *writes Sandra Speares.*

Time is not on anyone's side if the industry, and more particularly refineries, are to meet the demands of a potential 2020 implementation of the global sulphur cap of 0.5% with a review due this summer on availability of fuel supplies to meet the deadline.

Some bunker industry observers suggest that the availability of enough low sulphur fuel to meet requirements is no longer the issue and price is the predominant factor.

The IMO also has a challenge to ensure that its international voice prevails when faced with pressure from the EU, which has its own approach to measures to control emissions.

Discussions at MEPC on the adoption of a global CO_2 data collection system, requiring ships over 5,000gt to provide information on emissions were welcomed by the International Chamber of Shipping and, the organisation believes, it will mean member states are better placed to develop additional CO_2 reduction measures and respond to the Paris Agreement last year on climate change.

"Most of the details have been agreed, including the important fact that CO_2 reporting will be mandatory. We are confident that the IMO system will be fully adopted at the next MEPC meeting in October," said ICS secretary general, Peter Hinchliffe. "We believe that IMO member states have agreed an acceptable compromise between governments primarily interested in data on fuel consumption and CO_2 and those that wish to collect additional information, for example on so-called transport work."

"The priority now is to persuade the EU to adjust its unilateral regulation on the reporting and verification of individual ship emissions to make it compatible with what has now been agreed at IMO. While this may be an uphill struggle, we have been encouraged by the constructive attitude taken by EU member states this week, as well as those other nations that initially had concerns about the decision to make the IMO system mandatory."

ICS's "radical" proposal to develop an Intended IMO Determined Contribution (INDC) for CO_2 will be taken forward to the October meeting with other submissions made with respect to how IMO should respond to the Paris Agreement.

According to environmental lobby groups Transport & Environment and Seas at Risk, shipping's response to the Paris agreement was left in "disarray" because the sector could not agree on a work plan to develop a fair share contribution to the goal of limiting temperature increases to 1.5/2°C. "The IMO could only manage to kick the can down the road to its next meeting in October," the lobby groups maintained.

Bill Hemmings, shipping director at Transport & Environment, said: "Key developing countries seem to be in denial," while John Maggs of Seas At Risk, added: "The IMO has fallen flat on its face in the first test of its determination to tackle greenhouse gas emissions after Paris, unable even to agree to develop a work plan for reducing ship emissions." This he said was despite the fact that a large majority of member states and industry supported action.

Commenting on the EEDI issue in the run-up to the meeting the two NGOs said: "Since 2013 newly-built ships subject to the EEDI have performed much the same as those not covered". A recent report suggested two-thirds of containerships, half of general cargo ships and a quarter of tankers launched in 2015 already overshoot the requirement for 2020 without using innovative new technologies.

According to Sotiris Raptis, shipping policy officer at Transport & Environment: "EEDI standards as they currently stand are not stimulating the uptake of new technologies or driving efficiency improvements. The tightening of requirements for the design efficiency of new ships is one of the measures the IMO needs to implement in order to live up to the warming limit agreed in Paris."

The correspondence group on EEDI at MEPC has been instructed to report back to the next MEPC meeting in October after considering the status of technological developments for ro-ro cargo ships and ro-ro passenger ships based on information obtained from the EEDI database, as well as encourage further studies on the reduction rate of EEDI.

The group will also recommend within the current revision process whether the time periods, the EEDI reference line parameters for relevant ship types, and the reduction rates set out in regulation 21 should be retained or, if proven necessary, amended where appropriate. It will review the correction factors for ice class ships, ro-ro cargo ships, and ro-ro passenger ships with a view to preparing draft amendments to existing guidelines. *NA*

Communications

Securing the Smart Ship connection

Inmarsat, a British telecommunications company and partner in the Advanced Autonomous Waterborne Applications (AAWA) initiative being led by Rolls-Royce, has launched the first high-speed broadband solution to be globally available for maritime operators from a single provider.

The Fleet Xpress satellite network will facilitate the coming of Smart Ships, according to the company, providing reliable high-speed connectivity to support the constant levels of data transfer needed for the operation of such highly digitalised ships.

The new service combines Ka-band coverage with L-band coverage, respectively marrying high data speeds with "ultra-reliability", automatically switching between the two bandwidths to ensure a connection with a sufficient transfer rate.

Vice president and general manager at Inmarsat's partner, Network Innovations, Eric Verheylewegen, says: "Fleet Xpress is a game changer for the global maritime community…it delivers superior service even in areas that are not covered by traditional VSAT and provides the only truly unlimited L-band backup."

Nanjing Tanker Corporation of China has ordered the largest Inmarsat Fleet Xpress installation project to date for 70 of its ships. The aim is to deliver "smart shipping connectivity", which will help optimise the vessels' performance and improve crew communications and welfare.

Inmarsat has also announced that Singtel, a Singapore-based telecommunications firm, has entered into a strategic partnership with the company, and plans to integrate Singtel's Unified Threat Management (UTM) solution with Inmarsat hardware onboard ships.

The solution offers an advanced firewall, anti-virus, and intrusion and web-filtering, and is being adapted for maritime in response to its rapid digitalisation.

Managing director, business group, group enterprise at Singtel, Andrew Lim, says: "As maritime systems become more digital, it is imperative for the industry to protect data onboard ships against all forms of cyberattack. Our partnership with Inmarsat will provide maritime companies with a cyber security solution to meet rapidly evolving cyber threats, globally."

www.inmarsat.com

Fire safety

Changes to firefighting requirements

New amendments to the safety of life at sea convention (SOLAS) entered into force on 1 January,

Andrew Lim, managing director, business group, group enterprise at Singtel (left), signs a strategic partnership with Ronald Spithout, president of Inmarsat Maritime (right), to combat the growing threat of cyberattacks as digitalisation increases


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2016 regarding firefighting onboard vessels that have been built on or after this date and are designed to carry containers on or above the weather deck.

The amendments are to SOLAS Regulation II-2/10.7.3 and require ship owners to meet upgraded monitoring and equipment standards, according to Wilhelmsem Ships Service (WSS). These include carrying at least one water mist lance onboard the vessel and that ships designed to carry five or more tiers of containers on or above the weather deck must carry mobile water monitors. Monitors must also meet a list of new requirements, such as that they have a discharge nozzle of the dual-purpose spray or jet type with a minimum capacity of $60m^3/h$ (1,000litre min) and can operate both horizontally and vertically with a range of up to 90° and are capable of one man or unattended operation.

Business manager, safety, WSS, Andrew Sheriff, says: "As containerships have increased in size, so too has the need for effective measures to ensure the safety of the crew and cargo when substantial numbers of containers are carried on deck."

WSS's Unitor lance and X-flow water monitor have been specifically designed to meet all of the requirements of the new SOLAS rules, according to the company, and have been tested and type-approved by DNV GL.

Sheriff adds: "Although the water mist lance is specifically designed for use for containers on or above the weather deck, it can also be used in accommodation and deck areas to fight fires without having to enter the confirmed areas where a fire has started."

www.wilhelmsen.com/shipsservice

Software tools

End-to-end fabrication management

British software company AVEVA has combined two of its application suites to create an "end-to-end solution for steel design, detailing and fabrication" that will improve production efficiency.

Bocad, a structural steel detailing technology vendor acquired by AVEVA in 2012, will be paired with steel fabrication management solution vendor Fabtrol, which was acquired in 2015. The combined application suites will provide an integrated solution and include new capabilities procured through AVEVA's research and innovation team that will help steel fabricators cope with a challenging market.

The company points out that an increasing number of customers are turning to software to ensure their fabrications teams get the right information at the right time and Richard Brotherton, SVP, fabrication, AVEVA, explains there was a gap in the market for a "comprehensive, tailored solution for the specific needs of fabrication yards".

www.aveva.com

Smart Ships

Equipping the future

Rolls-Royce has announced that a new start-up company with expertise in electronics and automation will partner the Advanced Autonomous Waterborne Applications (AAWA) research project, providing system level architecture descriptions and integration plans that will enable the seamless operation of different technologies and technical solutions onboard vessels and in control centres.

The Finnish company, Brighthouse Intelligence, will design and implement cybersecurity solutions and aim to "productise" or "industrialise" AAWA studies consisting of internal networks, various sensor packages and radio links.

Markku Sahlström, managing director, Brighthouse Intelligence, explains: "Industrialising AAWA studies start with demo environments and development platforms which are first built into laboratory environments and gradually moved onboard of test vessels. [The] focus is first in assisting systems on a way towards the autonomy. Our role is to ensure that industrial demands are taken into account in every development phase of the project, [and the] outcome being not only technical specifications and reports but also systems that are ready to be built and taken into use."

The company was established in December of last year and has emerged as an offshoot of the mobile device business; employees of the company have experience with Nokia and Microsoft.

While discussing AAWA's collaboration, Oskar Levander said: "either you need to join forces or…new players will come". This reaffirms the idea that companies must be prepared to make room for new digital alliances to keep pace with digitalisation in shipping.

www.brighthouse.fi

Accommodation & interiors

Clean sweep for Bolidt flooring

Bolidt Synthetic Products & Systems is set to provide deck and flooring products for many of the world's largest cruise lines, including TUI Cruises, MSC Cruises, Norwegian Cruise Line (NCL), Holland America Line (HAL), Royal Carribean Cruise Line (RCCL) and Viking Cruises. The company will cater to the next


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Flooring onboard *Quantum of the Seas* shows what might be in store for *Harmony of the Seas* and *Ovation of the Seas*

generation of cruise vessels, with at least 12 commissions in progress or on order. *MSC Meraviglia* is among those included and is being built at STX France; the first in MSC's Vista series. Bolidt is contractually obliged to install balcony decks in block stages in order to save money and time for the yard. Director of Bolidt's maritime division, Jacco van Overbeek, says: "If we install in block stages, the blocks are already inside the big tents which are required to protect them. As a result, there is no need to provide any additional weather protection to install the balconies once the blocks have been put together for the complete vessel." A sister ship and two other vessels to be built for MSC Cruises at STX France will also feature Bolidt decking and flooring materials. Orders include Bolideck's Future Teak, Select Soft Teak Effect, Select Soft and Select Hard systems.

Further projects include *Norwegian Joy* for NCL, RCCI's *Harmony of the Seas* and *Ovation of the Seas*, *Mein Schiff 6*, *7* and *8*, HAL's *Koningsdam*, and Viking Cruises' *Viking Sea*.
www.bolidt.com

Fire safety

Locating onboard fires

Sea-Fire, a provider of marine fire suppression technology, can pinpoint the precise location of onboard fires where traditional zone-based fire detection systems are non-specific and only indicate a general response, according to the company.

Triton 2 is an "addressable fire detection panel" that detects the location as well as the type of incident, including smoke, fire or detector fault incidents.

It can be deployed on megayachts and medium to large commercial vessels and can operate in temperatures of 5˚C to 70˚C. The panel can drive up to 252 addressable devices over two integrated loops and can be expanded if necessary. In addition, it features an electrical supply crossover that offers redundancy during power interruptions.

The system has been approved by the EU Marine Equipment Directive (MED) wheelmark.
www.sea-fire.co.uk

Monitoring

New guidance on condition monitoring

American classification society, ABS, has released new guidance material on condition monitoring techniques and machinery reliability and maintenance management programmes.

The two documents, "Guidance Notes on Condition Monitoring Techniques" and "Guide for Surveys Based on Machinery Reliability and Maintenance Techniques", will respectively aid owners and operators in their selection of monitoring techniques and provide updated methods for achieving classification notations.

The guidance notes provide a summary of monitoring techniques and map techniques to expectations and needs.

The guide explains ABS' process and requirements for its review of design submittals, but also shows how they analyse designs and maintenance plans throughout a vessel's lifecycle.

Chief technology officer, Howard Fireman says: "There have been significant advances in condition monitoring software and diagnostic technologies that have the potential to improve operational efficiency and enhance overall safety…[and] these changes are reflected in these newly released documents."
www.eagle.org


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Anmax and LR team up in CFD scaling project

Recent presentations in technical journals and at specialised conferences emphasise the need for credible ship scale Computational Fluid Dynamics modelling. Dr Dmitriy Ponkratov of the Lloyd's Register Technical Investigations Department outlines the class society's validation project

The value of ship scale CFD to ship designers and ship owners goes beyond predicting accurate performance at the conceptual stage. It can be used to help identify causes of poor performance in existing vessels, predict the effectiveness of energy saving measures that improve the hydrodynamics, and simultaneously account for aerodynamic flows around the vessel.

Accurate ship scale flow modelling can also assist in failure investigations such as propeller cavitation and other sources of ship noise and vibration. Undoubtedly, some of these investigations can be performed through model scale testing; however a number of assumptions are often required due to the inability to match all relevant scales, such as Reynolds and Froude, simultaneously.

Figure 1: General cargo vessel *Regal* in a drydock prior to the trials

Software developments and the decrease in price of computational power have made ship scale simulations widely available. Despite this, as mentioned for example by CD-Adapco's marine director, Dr. Dejan Radosavljević (*The Naval Architect* July/August 2015), the uptake by the industry is not high, especially among ship owners. One of the reasons for this reluctance is the lack of comprehensive validation that would give both the users and the ship owners confidence in the methods.

Due to the well-established practices of conducting model tests in a towing tank, there are a number of public domain cases for model scale CFD validation (such as the well-known containership and VLCC tested by KRISO). However, there is a severe shortage of fully documented cases for ship scale CFD validation available in the public domain. This is due to the high cost of the trials required and the challenges of obtaining permission from the stakeholders to publish the hull and propeller geometries.

Lloyd's Register (LR) has a number of loyal clients who not only class their ships with LR, but are willing to contribute to the development of the marine industry by participating in challenging research projects. One of these clients, the Anmax

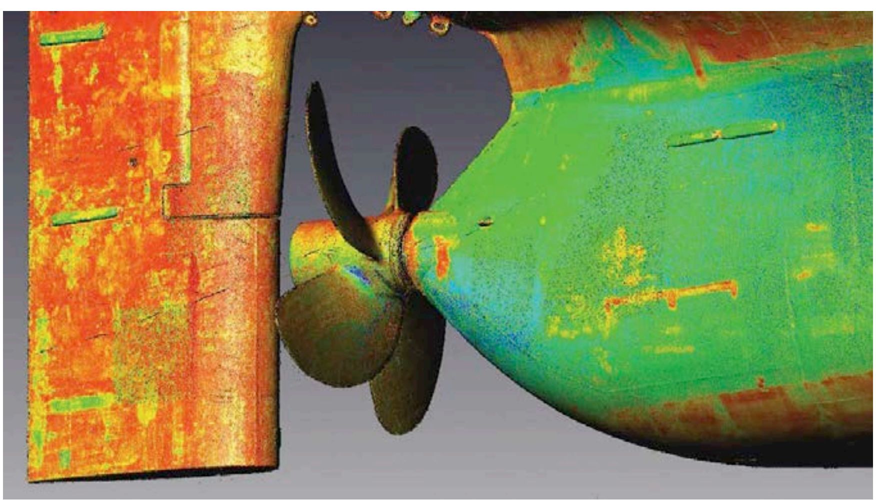

Figure 2: Results of a 3D laser scan performed while the vessel was in drydock

Trading Corporation, has recently provided the LR Technical Investigations Department (TID) with access to one of its ships to perform in-service performance measurements for the purpose of ship scale benchmarking that can be shared with the marine research community.

The subject vessel, *Regal* (Figure 1), is an ideal candidate for the ship scale CFD benchmarking as it is a single screw general cargo vessel (150m x 23m x 8m) with a simple configuration: no thrusters, no bulbous bulb and no energy saving devices. The vessel is equipped with a four bladed fixed pitch propeller and a semi spade rudder.

The objective of the trials was to collect information related to ship hydrodynamics that could be further used for ship scale CFD simulation validation of self-propulsion and cavitation in deep and shallow water. Apart from ship performance characteristics such as speed, heading, slip angle, propeller speed, propeller thrust and torque, the environmental conditions defined by wave height and direction, wind and current were also recorded. The trials were carried out on the Black Sea in the summer of 2015 to minimise the risk of harsh weather conditions.

Prior to the trials, the vessel was dry-docked for hull cleaning and the propeller surface was polished. The hull, rudder and propeller were then 3D laser scanned to get an accurate geometric representation of the in-service geometry. Figure 2 shows the results of a high resolution 3D scan where every weld seam on the hull surface was resolved. While the vessel was in drydock, LR TID specialists installed performance measuring equipment onboard. All the equipment was checked and calibrated in the TID laboratory prior to installation. The following were installed onboard:

- Shaft optical sensor to record Propeller RPM
- Independent GPS unit to record vessel speed, position and slip angle
- Full bridge in one strain gauge on the shaft line to record Propeller Torque 1
- Full bridge in one strain gauge on the same shaft line to record Propeller Torque 2 (independent to Torque 1 in order to cross check with Torque 1)
- Full bridge in two strain gauges on the shaft line to record Propeller Thrust 1
- Full bridge in two strain gauges on the same shaft to record Propeller Thrust 2 (independent to Thrust 1 in order to cross check with Thrust 1)
- Acoustic emission on the shaft – two independent sets to record acoustic signal from cavitation events on the propeller
- Acoustic emission on the bearing house – two independent sets
- Two borescopes (one on port side, one on starboard side) with high speed cameras to observe and video cavitation events on the propeller.
- Draw wire sensor to independently record Rudder angle
- Two independent sensors to measure the vessel's dynamic trim
- Two independent sensors to measure the vessel's Roll
- GoPro cameras to record the environmental conditions

Figure 3: Borescope with high speed camera installed through the shell plate in the engine room

For the borescope installation, which is used to observe cavitation, the shell plate in the engine room was drilled and tapped at specific locations facilitating port and starboard views of the propeller. Video recordings were made on starboard and port side simultaneously with two high-speed video cameras, which were set to 200 frames per second and mounted on a borescope. The set-up for the port side position is shown in Figure 3 and some frames from the high speed video recorded during trials are shown in Figure 4.

High speed video data was synchronised with acoustic emissions (AE) signals measured on the shaft bearing houses and the shaft line using four 150kHz resonant AE sensors. The signal was sampled at 10kHz with National Instruments "cDAQ" technology. The AE data provides a relative, quantitative assessment of the aggressiveness of energy imparted to the propeller surface during the growth and collapse phases of cavitation development. This technique was developed by LR TID and has been proved to be an effective technique on over 20 projects in the past 10 years.

Due to the size of the data file generated by the high video frame rate, video and AE signal recordings were limited to 20 seconds for each section. During data analysis and post-processing, the AE signals and high-speed videos were synchronised using MATLAB. As thrust and torque measurements do not require high frequency output, the signal was sampled at 2kHz and was recorded during all runs.

In order to record the shaft speed, a reflecting tape was glued on the shaft line and an optical sensor was mounted close to the shaft. Each time the tape passed the sensor window a voltage signal was transmitted to a recording device. For ease of reference, the tape was fitted to the shaft in line with the sensor window when the key blade was located in the top dead centre, resulting in a simultaneous recording of the key blade position.


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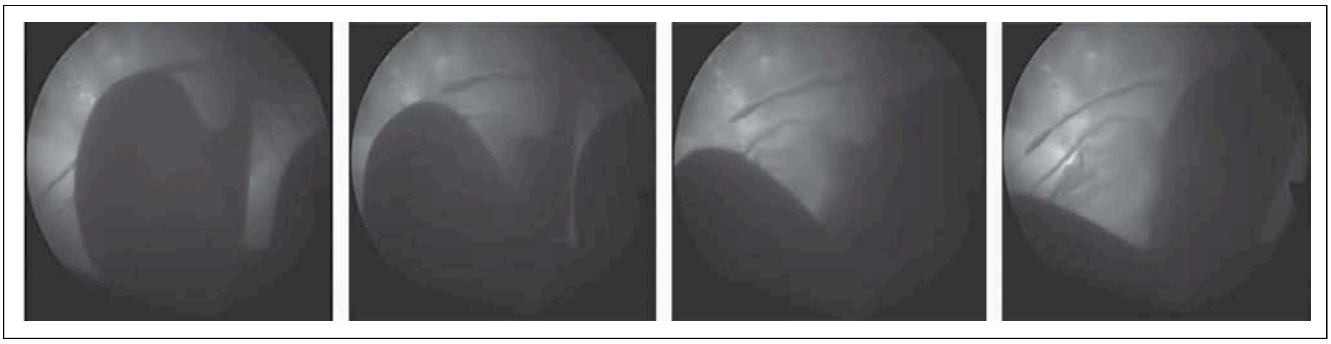

Figure 4: Frames from high speed video showing the tip vortex propeller cavitation

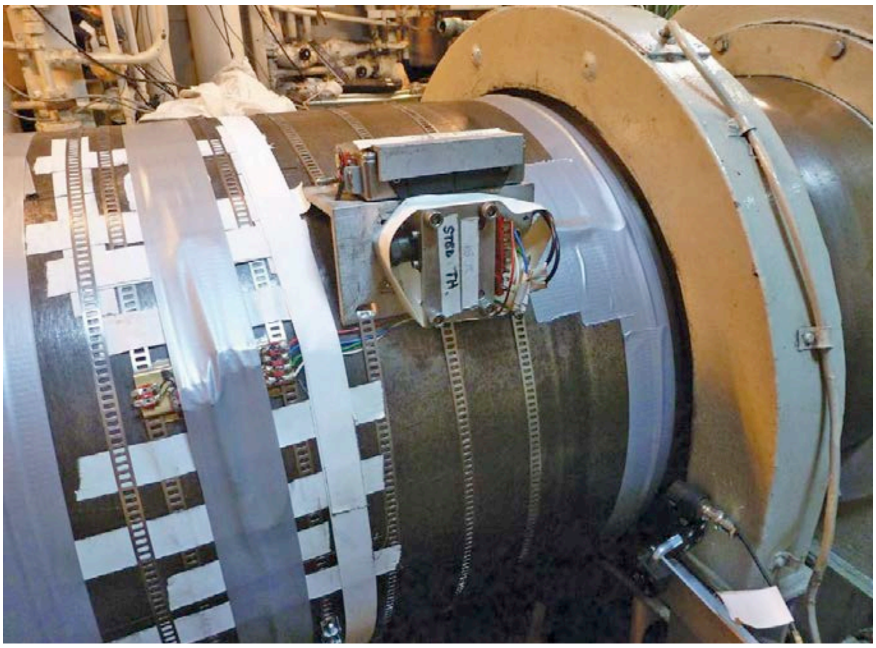

Figure 5: Torque sensors with the telemetry kit installed on the shaft

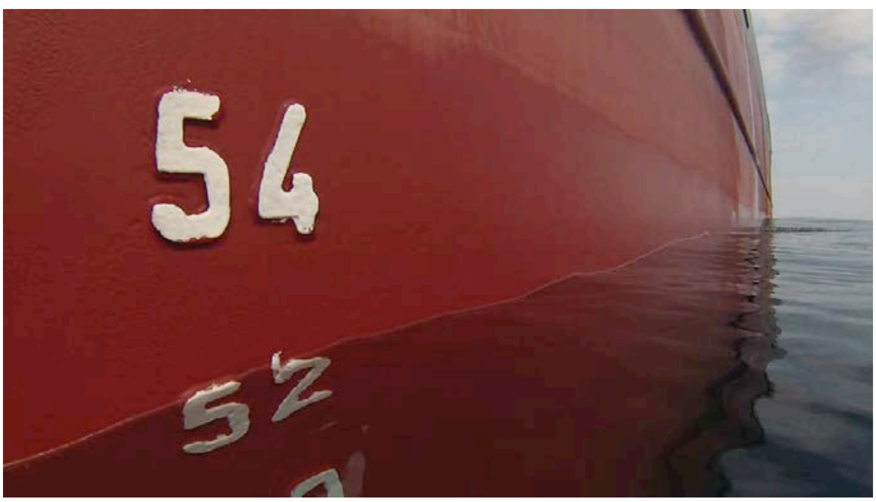

Figure 6: Stopping the vessel at sea to measure draughts and take water samples

The propeller thrust and torque were measured by strain gauges similar to those used in Formula 1 cars for various measurements, including the wheel axis moment. The installation of the gauges on the shaft was the most difficult task and required careful treatment due to gauge sensitivity. Before each gauge was fitted, the corresponding area of the shaft was manually polished with sand paper and longitudinal and transversal axes were drawn. Before and after the installation, all strain gauges were tested by the strain indicator and the gauges out of balance were identified. The amplifier and battery pack were also mounted to the shaft (Figure 5). Six batteries supplied power to the shaft amplifier for the duration of the sea trials. The aerial was glued around the shaft and the signal pickup was mounted close to the aerial so that the amplified signal could be transmitted to the recording software.

The measurement of the propeller torque requires only one full-bridged strain gauge and the values are usually attained to a high degree of accuracy. The torsional deformation of the shaft (usually on the order of a hundred micro strains) is generally much higher than equipment tolerances (usually 10 micro strains). The propeller thrust on the other hand is the most challenging value to measure, as the longitudinal deformation of the shaft is in the same order of magnitude as the equipment tolerances. Hence, even careful installation of the thrust strain gauges does not guarantee a high accuracy of measurements. In order to build a full bridge for the thrust measurements, two strain gauges were glued on the opposite sides of the shaft and a heating compensator was applied.

Before commencement of thrust and torque measurements, it is necessary to determine the zero level when the shaft is stationary and there are no forces or moments acting on the shaft. Theoretically, this can be done after the installation whilst the ship is alongside. However, the zero level on the “cold” shaft will not necessarily be the same as on the

Figure 7: Measurements of water temperature to determine the water density

"warmed" shaft during the trials, hence the heating impact would be ignored. Stopping the shaft at sea for a short time to determine the zero level of a heated shaft is also impractical, as the ship movement due to the inertia would even create forces and moments on the stopped shaft. The practical solution, which was applied in the current case, was to record zero thrust and torque after about 30 minutes when the vessel was stopped at sea. The recorded strain values were then post-processed in order to obtain the corrected values for the thrust and torque.

Since redundant strain gauges were installed on the shaft, it was possible to cross check the measured values between them. As stated earlier, the torque results are usually the most reliable and the cross check confirmed this, revealing an acceptable maximum difference of 5% from two independent torque sensors. For the thrust cross check the difference from two independent installations was larger so the thrust values should be used indicatively.

Apart from the strain gauges, a draw wire sensor was mounted on the rudder stock to measure the rudder angles. After the installation, and whilst the ship was alongside, the rudder was applied in the range of 20^0 port to 20^0 starboard, in 5^0 steps in order to calibrate the sensor and to determine the dependence of the wire displacement on the rudder angle. After calibration, the resulting coefficient was applied in the recording software in order to acquire the signal directly in degrees.

During the periods of the trial when the vessel was stopped, the draughts (forward, aft and middle on port and starboard sides) were recorded by a camera (Figure 6), water temperature was measured (Figure 7) and water samples taken in order to keep the record of water density.

The speed tests were conducted under various power conditions at ballast draught at deep and shallow water. The aforementioned quantities were measured for all tests. The weather conditions recorded during the trial show reasonably calm conditions, (Figure 8) which helps to minimise the uncertainties related to environmental impact. The ship speed was recorded for all double runs by an independent GPS system installed on the navigation bridge. Figure 9 shows the track of the runs for speed tests.

The trial has resulted in a collection of ship scale data that defines the vessel speed/power relationship, dynamic trim, and cavitation behaviour including acoustic response for a range of environmental conditions and manoeuvres. Together with the high resolution hull and propeller geometries, this data forms a valuable resource for validation and developing the science of naval architecture.

LR in cooperation with Anmax Trading Corporation is now proposing to raise the level of trust for ship scale CFD modelling in the marine industry by releasing some of this data to the community through an international workshop.

Participants in the workshop will be provided with the hull and propeller geometries as well as the sea trial conditions. They will be asked to submit CFD simulations of the ship scale vessel which will then be shared and discussed at the workshop together with the ship scale trials data. An outcome of the workshop will be an extensive database of CFD results for one

Figure 8: Environmental conditions during the trials

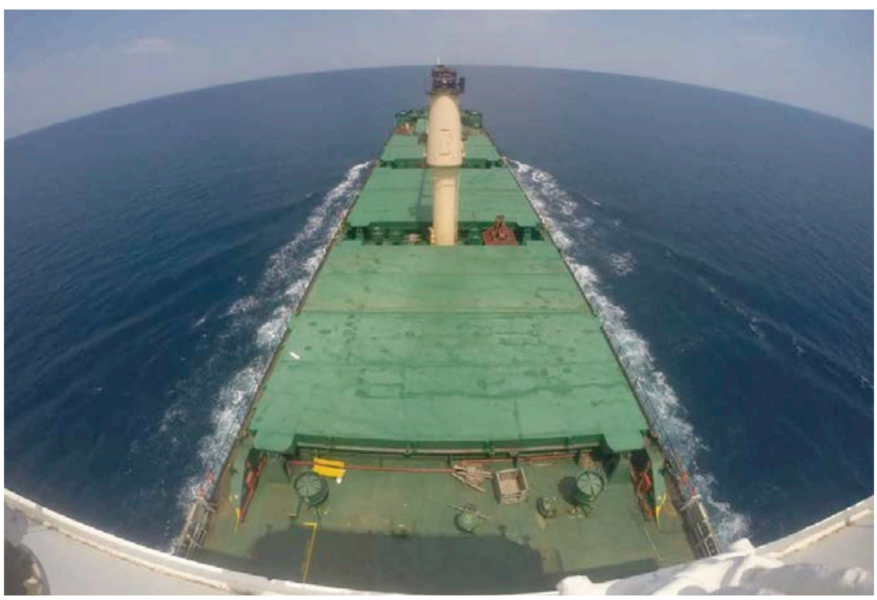


Figure 9: GPS track of double runs performed during the trials

case that highlights the impact of modelling approaches, leading to the development of best practice for ship scale marine CFD. Moreover, it will provide a forum for researchers and commercial practitioners of marine CFD to network and develop ideas for future collaborative work.

The workshop is planned for November 2016 at Lloyd's Register's Global Technology Centre in Southampton, UK. Further details will be released on the LR website in the near future. *NA*

For further information in the meantime, please contact Dr Dmitriy Ponkratov at Dmitriy.Ponkratov@lr.org

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Technology tested by hull monitoring standard

The First Hull Performance & Insight Conference, 13-15 April 2016, brought developers and users together to exchange first experiences in the evolving field of performance management, especially in light of the ISO 19030 draft. Apparently the topic is very much in vogue. Volker Bertram reports

Many fuel-saving technologies are hardly adopted, because the industry does not trust the promises or because contracts fail to create win-win situations. Typical examples are advanced hull coatings and some propulsion-improving devices. ISO 19030 is expected to bring major improvements in this respect.

The ISO 19030 standard outlines general principles of hull and propeller performance for fleet in service and is expected to be published by June 2016. See Soyland & Oftedahl for a good introduction.

The response to the conference was such that the organisers had to turn away those who took too long to make up their minds, and it shows the industry interest that the subject generates. With 80 participants, a third of who were ship operators, the festive hall of the Castello di Pavone in Italy was packed to capacity.

ISO 19030 was in the position of a future son-in-law being presented for the first time: inspected with polite interest, but not yet adopted wholeheartedly except by its own parents. "There still remains controversy [over the value of performance monitoring systems]", summed up Ryo Kakuta (NYK Lines, MTI). While the present may be characterised by some reserve, the future – as always – appears brighter:

"Advances in measurement of hull performance should allow buyers and sellers of technologies to make better decisions and in shorter time. Performance monitoring should also allow aligning various stakeholder interests better than now. Contracts based on the measured performance improvement will open the door for benefit sharing and get more people to invest in energy efficiency," said Geir Axel Oftedahl (Jotun), secretary of ISO 19030.

Hull Performance Monitoring is used to guide business decisions such as selecting coating and cleaning strategies. The example here is DNV GL's ECO Insight (source: DNV GL)

Data acquisition

ISO 19030 highlights the need for accurate data acquisition. If the sensors give wrong or no data then performance monitoring is doomed from the beginning ("garbage in – garbage out"). In practice, a particular challenge is the implementation of stable data acquisition on older ships. "With growing experience it becomes evident that a strong focus must be on acquisition and integration of meaningful performance data onboard," said Michael vom Baur (Hoppe Marine). Several other sensor experts sang a similar tune.

Propeller shaft power and speed through water are the two most important parameters to monitor. Most experts see torque and rpm measurements as indispensable, but not all. Fumi Yakabe (JSTRA) reflected the position of the Japanese delegation that engine performance (fuel consumption) may be used to deduce hull performance, but admitted that this approach only works if the engine is in prime condition and does not in itself contribute spurious or time-dependent performance losses. Performance monitoring becomes simpler and more accurate when we separate hydrodynamic performance (downstream of the propeller shaft torque measuring point) and engine performance (upstream of that point). However, there was already general agreement with Erik Hagestuen (Kyma) that it is important to also measure engine performance (fuel consumption) for a complete performance picture of a vessel.

While splitting engine performance and hydrodynamic performance is relatively straightforward when torque is measured, splitting propeller and hull performance remains a big challenge. ISO 19030 acknowledges the difficulties and leaves it open whether at a later point in time hull performance and propeller performance may be separated. Sergiu Paraeli (Jotun) discussed in detail the challenges we face even if we have separate thrust measurement. In theory, the problem is solved, but in practice the available sensor accuracy and the ambient noise in sensor signals prevent satisfactory results. Any method pretending to have the problem solved should thus be tested in a sensitivity analysis; then generally we see with sobering clarity the large uncertainty in results. Erik van Ballegooijen (VAF Instruments) showed a silver lining on the horizon: the optical measurement approach for thrust and torque increases accuracy over the classical strain gauges. Now all we need is wider roll-out of this technology in the world fleet.

But the Achilles heel remains speed through water. Mark Bos (BMT Smart) gave a good summary: "A speed log needs calibration to avoid a bias in the measurement. Over time the bias can change and recalibration of the speed log is required. But it is not obvious how to calibrate the speed log if the actual speed through water is unknown. It is difficult to correctly calibrate the speed log without dedicated speed trials and this is not commonly done when the vessel is in service." Bos recommended to improve the current ISO 19030 procedure by combining the much more accurate speed over ground with current prediction from MetOcean providers. In a case study, this gave more plausible results than direct speed log measurements. Jan Wienke (DNV GL) added that speed log measurements depend somewhat on draft and trim, leading to additional uncertainty.

As a final thought on data acquisition, Thilo Dückert (DNV GL) pointed out that both data quality and data frequency affect performance monitoring, but data quality was more important for good results. Dückert argued that human reporting comes with some quality control during data acquisition while automatic systems may record nonsense for a long time without anybody noticing it.

50 Shades of Grey

Raw data needs to be corrected ("normalised" in expert jargon) for varying operational and ambient conditions. In essence, we need to make numbers comparable, correcting for differences to a standard reference condition. This task requires a model (or algorithm) to determine, for example, differences in power requirements for different draft or different wind conditions. Such models are derived in different ways and have largely varying accuracy. Michael Haranen (Napa) classified approaches as white-box, grey-box and black-box. White-box approaches are based on complete physical insight. We could also call them first-principle approaches. A comprehensive CFD model for ships in wind and waves with a working propeller would be such a white-box model. The key problem of white-box models is creating a complete physical model of all effects, with all interactions, and still having reasonable computational response. Black-box approaches use exclusively machine learning or system identification. Here we don't understand the relation between input and output variables, but we should at least know all input variables driving the output. And grey-box models use some physical insight and some empirical fitting. A key problem of black-box models is dealing with high levels of measurement noise / sensor errors.

All solutions offered at present are grey-box models. But we see 50 shades of grey. Some are dark grey, relying heavily on machine learning. Some are light grey, using CFD extensively. And some are muddy-grey. Listening to assorted presentations by vendors, I was reminded of the bible (another good book to read): Why do you see the speck that is in your brother's eye, but do not notice the log that is in your own eye?

Michael Haranen (Napa) pointed out that black-box methods can only predict what they have seen before. Extrapolation beyond their knowledge base leads to large errors. Antti Solonen (Eniram) admitted that black-box models needed monitoring for a "long enough" time period (covering all relevant speed levels and loading conditions), but not so long that fouling changes significantly. Wojciech Gorski (Enamor) elaborated on the difficulties of machine learning as the number of influencing variables ("dimensions") and their range of variability increases. The (nearly) black-box approach works well for a few ship types, but faces big problems when there are many variables with a wide range of variation. For large oil tankers (with essentially only two draft-trim conditions) or cruise vessels (very little variation in draft), it appears to be well suited, but for containerships it is unrealistic.

The assorted approaches differ widely in a core component of performance monitoring: the hydrodynamic model to predict power P as a function of speed V, draft and trim. In reality, this function is highly complicated, but many performance monitoring systems still try to cut corners here: "we assume power to be proportional to surface area" or "we use the well-known relation $P = aV^b$", where some authors use b=3 (a.k.a. third-power law or Admiralty formula), some b=2.7, some b=4 or even b=6. Take your pick. Others use more sophisticated ship design approaches, such as Lap-Keller, Guldhammer-Harvald or Holtrop-Mennen. See Dückert et al. to explain why all these models are unsuitable.

Design formulas are no good for the typical off-design operation. And complex functions cannot be globally replaced by simple approximations. Only for local, very limited interpolation, simple approximations may work, e.g. the third-power law as found in ISO 19030 within 5% from a solid baseline (found in model tests or CFD). Both Andreas Krapp (Jotun) and Tsuyoshi Ishiguro (JMUC) supported this stance, concluding that a detailed CFD-derived knowledge base of power as a function of speed, draft and trim was vital for containerships.

This is a bitter pill, as simple means cheap, while accurate and reliable comes at a price. As one participant formulated it: "The ISO 19030 approach [requiring dense knowledge bases for ships with large variations in draft, trim and speed] is difficult for many parties to implement." But apparently, in this aspect you cannot have cheap and good at the same time. CFD is bound to play a more important role in future performance monitoring models.

This brings us to the question whether we should use the classical towing tank or the numerical towing tank. Only Ryo

Fouling deteriorates ship performance and accounts for an estimated 10% of the world fleet's fuel consumption and contribution to Greenhouse gases (source Jotun)

Kakuta (MTI) believed that "conducting towing tank tests is the best way". Two propeller manufacturers, Greitsch (MMG) and Fukuda (Nakashima Propellers), saw CFD as the clearly preferred option, but welcomed in-service monitoring data for validation of their numerical methods. Michel Visonneau (Ecole Centrale de Nantes) summarised the state of the art: "It is well accepted now that CFD is a mature tool for steady-state ship hydrodynamic applications such as resistance [and power] in calm water." It remains to hope that CFD will then in time become more widely adopted, as prices fall and its importance for hull performance monitoring is more widely perceived.

Scatter unavoidable

Even with the best data acquisition and hydrodynamic model for correcting operational variations, there will be a scatter in results due to wind and waves. Several papers discussed this field adding to our understanding.

The Japanese are always good for supporting their statements with meticulous data harvesting and analyses. Tsuyoshi Ishiguro (JMUC) showed that the power increase due to wind and waves may exceed 10% for Bft 4 in head waves. As a consequence, he recommended a more flexible approach to filtering than currently found in ISO 19030: filtering in head and bow quartering at 3 Bft and other wind directions at 4 Bft. However, he confirmed the ISO 19030 recommendation for filtering for sea states until better correction methods will be available (both better simulation methods and more accurate measurement of local wave fields, e.g. derived from onboard radar).

The same message was drummed home by Volker Bertram (DNV GL): at present, we have no accurate and affordable correction for added resistance in waves; while some 3D simulation methods give good results for added resistance in waves, we need better wave measurement in order to really progress. Until then, the best filter for sea state and wind is as recommended by ISO 19030.

Mark Bos (BMT Smart) contributed insights on ambient conditions. Current varies over water depth: Bos cited 0.5kn variation in current speed over 12m (i.e. a typical draft of a ship), making the very definition of speed through water difficult for higher current speeds. He also pointed out that wind measurements are frequently distorted by the presence of the ship, recommending instead MetOcean data. For a laden Suezmax tanker, "on average for all wind directions the anemometer wind speed is 20% higher than the MetOcean wind speed". Finally, he brought the effect of water temperature back on the table for discussion. ISO 19030 lists sea water temperature among the data to be recorded, but omits a correction for it in the standard approach. Bos gives an illustrative example: water temperature fluctuations in the Mediterranean Sea may give ~2% change in performance for a tanker. It may thus be recommended to include such a correction, as a voluntary improvement over the standard approach.

A good first step

In summary, ISO 19030 seems to be largely on the right track, but with potential for improvement. Consolidation in the market is likely, but not to the extreme of one method to rule them all (and in the darkness bind them). The flexibility of ISO 19030, a necessity born from the need to get enough international approval, may well be a blessing in disguise, allowing us all some freedom until we have collectively gathered more facts to feel comfortable with stringent recommendations.

The growing adoption of performance monitoring as such is very encouraging. However, "performance monitoring and management solutions do not save fuel by themselves. It is up to the recipient to make use of it," as Falko Fritz (Skysails) reminds us.

Despite all controversial discussion, there was general support for the HullPIC conference itself. Both developers and users of performance monitoring systems welcomed the aggregation and exchange of knowledge leading to better understanding of ISO 19030. In the words of Albus Dumbledore (and performance monitoring appears to involve some magic, whether black or white): "Understanding is the first step to acceptance." Not surprisingly, we will have a 2nd HullPIC in 2017 to continue the dialogue and perhaps move forward from understanding to acceptance. *NA*

Volker Bertram, Dept. Mech. & Mechatronic Eng., Stellenbosch University (also DNV GL),

Proceedings of the conference can be downloaded from www.HullPIC.info. References given above are all from the HullPIC 2016 proceedings

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Jiangsu shipbuilding or the survival of the fittest

In spite of the cut throat competition between yards both within China and from outside the country, the Jiangsu yards have shown steady development, writes Wu Xiuxia

Last year witnessed an increasing pace of change in the Chinese shipbuilding industry as solutions to the industry's oversupply and backward means of production were found.

Focusing on the theme of "efficiency, quality improvement and delivery guarantee", Jiangsu Province's shipping industry has given full play to the role of key shipping enterprises, guiding the enterprises to develop risk-resistance, competence and encouraging a larger percentage of high-end green vessels. The whole industry has been developing steadily.

Jiangsu shipyards have increased their productivity through the modernisation of their yards

Prominence of the key shipping enterprises

In 2015, with the fast elimination of those enterprises that have failed to modernise, unqualified production has been gradually phased out. Some key shipping enterprises in Jiangsu Province have effectively encountered different risks, laying the foundations for future development and improving management competence.

Currently, shipping enterprises in Jiangsu Nantong, Yangzhou and Taizhou bases possess the production capacity to cover the series from shallow water to deep water vessels, but they have also developed the capacity for designing and manufacturing all types of ships except luxury cruise liners. Some of the most competitive enterprises focus closely on the demand of the market and optimise the current product structures. Some have gained a competitive edge in such vessels with energy-saving and environmentally-friendly measures.

Outperforming vessels have also introduced their distinctive products into the international market. For example, NACKS, the joint venture between Nantong COSCO and Kawasaki Heavy Industries of Japan, has deployed its upgrade strategy for large-size containerships and clean-energy vessels; the yard is moving to the smart manufacturing stage. Seven types of vessels, such as 300,000dwt VLCC and VLOCs, 5,000-6,200 unit car carriers, 5,400TEU, 10,000TEU and 13,000TEU container vessels, have bridged the gap between China-built and international ships.

NACKS has established a high-end product image through its excellent performance and quality. Yangzijiang Shipbuilding (Holdings) Ltd. has implemented a series of R&D programmes, with the most significant project the development of the 10,000TEU containership series, which is popular in the market due to its volume, energy consumption and emissions performance.

Taizhou Kouan Shipbuilding Co., Ltd is persistent with its policy of balance between development and progress, and its orders in-hand will keep the yard busy until 2018. Nantong COSCO Shipyard had delivered its semi-submersible accommodation platforms Gaode No. 1 and Gaode No.2 to Mexico Cotemar. With the development of these key enterprises, Jiangsu shipbuilding industry's innovation plan has overcome technology barriers and promoted sustainable development.

Jiangsu's industry head says that shipbuilding in Jiangsu will actively fulfil its mission for innovation-driven development in the future. Focusing on the structural adjustment and strategy transformation, it is to integrate the innovation factors and construct the technical innovation system, guiding and supporting the enterprises to build R&D centres for national level and provincial level offshore engineering and ship facilities. It will also facilitate the development of independent patent vessel types.

Consistent with this strategy of "high-end road, brand promotion and diversified development", Jiangsu has formed its offshore business to feature professionalism, large production, maturity, and high efficiency. The province is working on promoting a series of model projects and facilitating the most prestigious ones.

Faster pace in industry upgrading

In 2015 many shipbuilders in Jiangsu were dedicated to enhancing management capacity. Yangzijiang Shipbuilding (Holdings) Ltd., Kouan Shipbuilding, NACKS, etc., have increased their investment and corresponding application in R&D in the area of new assembly, new craftsmanship and new methods. Information and advanced manufacturing have also been included in development.

Jiangsu's constant increase in R&D provides incentives for prestigious enterprises to develop new ships. So, in the process of upgrading the industry, the percentage of bulk carriers has decreased while the development of high-end green ships has increased. With the establishment of the method of assembly, Jiangsu Province has dramatically improved its technology, management, R&D, and efficiency. The manufacturing period for the construction of a vessel is now similar to that of competing Japanese and South Korean ship yards.

Some enterprises have initiated 'Smart Manufacturing' in response to the emergence of the national policies, 'China Manufacture 2025' and 'Internet Plus'. NACKS has consecutively introduced automatic production lines of shaped steel, bar steel and robot welding, and many other enterprises are also moving in this direction.

Jiangsu New Times Shipbuilding introduced pipe welding robots at the establishment of its shipyard. The replacement of manual labour not only reduces the burden on workers, but also guarantees the quality of work and improves efficiency. The head of the shipyard says that with the upgrading of the industry, it is an unavoidable stage for the shipbuilders to undergo if they want to survive and outperform their competitors. To realise smart manufacturing, then, remains a voluntary choice for shipbuilders, but it clearly has benefits.

A visible hand and its power

Last year was also a period of conspicuous merging and separation in the shipping industry. The industry's concentration has become more obvious and the influence of structural adjustment is also prominent.

Ever since 2014, three bases in Jiangsu have removed old fashioned production practices and excessive capacity by means of mergers, replacements and consolidation. In 2015, the progress of absorbing excessive capacity was witnessed by all; a number of unqualified shipyards fell by the wayside where other shipyards were guided by industry departments and their resources, namely coastline, property, human resources, finance, etc., and those yards absorbed into the shipyards whose production methods were more progressive. In this way, Jiangsu's shipbuilding industry has gradually transformed its development from 'quantity growth' to 'quality growth'. Yizheng City has solved the problem of excessive capacity by reducing its capacity by one million tonnes in 2015.

The market chooses the healthy yards and eliminates the unfit ones in the current industry cold spell. With multiple development strategies, product adjustment, effective management, and a focus on high-tech & high value-added products, the competent enterprises further prove their value and competitiveness, surviving the freeze. *NA*

A critical review of EEDI for ro-ro ships

This paper critically reviews the adopted Energy Efficiency Design Index formulation according to IMO Resolution MEPC 245(66) for ro-ro ships. It proposes improved formulations for the ship specific correction factor [fjRoRo] of EEDI, which were derived by the processing of a large sample of data from ro-pax ships built in the period 1990-2012

A comparative study on the Energy Efficiency Design Index formulation (EEDI) with a sample of eight ro-pax ships of different sizes relieves an irrational sensitivity with respect to the main parameters in the currently adopted EEDI, and raises some justified questions regarding the maturity of the EEDI reference lines for ro-pax adopted so far by IMO. This comes in addition to justified safety concerns with respect to the minimum powering requirements for safe ro-pax ship operations in adverse sea conditions.

A very optimistic projection on the greenhouse gas (GHG) emissions from international shipping during 2007-2012 was confirmed; namely the fact that the global shipping industry's GHG emissions were reduced from 2.8% of the world's total GHG emissions in year 2007 to 2.2% in year 2012, which corresponds to a decrease of 20% of the shipping GHG emissions within a five year period! This is a remarkable reduction that was made possible with the introduction of mainly operational efficiency measures in the existing and newly-introduced fleets worldwide.

Even though the EEDI concept development was originally triggered by the prospects of introducing new design and technology measures, operational measures dominated the scene. Moreover, as the introduction of the EEDI happened in a period of high fuel prices, the shipping industry responded by adopting slow steaming, while shipbuilders often simply reduced the installed propulsion power, without caring for negative side effects, such as ship's safety, especially in adverse conditions.

Reduced installed propulsion power and reduced steering/manoeuvring capability in confined waters is expected to further

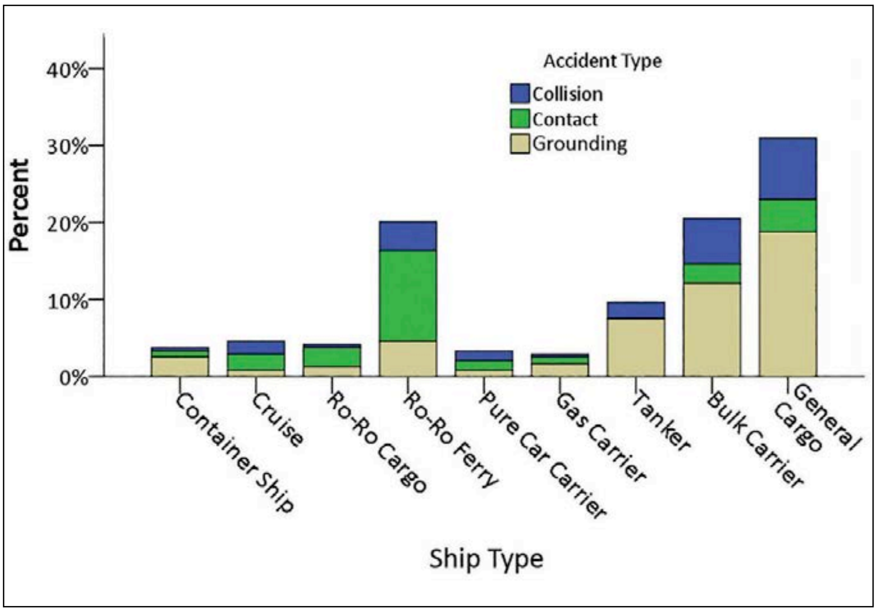


Figure 1: Percentage of ship types engaged in navigational accidents in the presence of adverse weather conditions by accident types, project SHOPERA

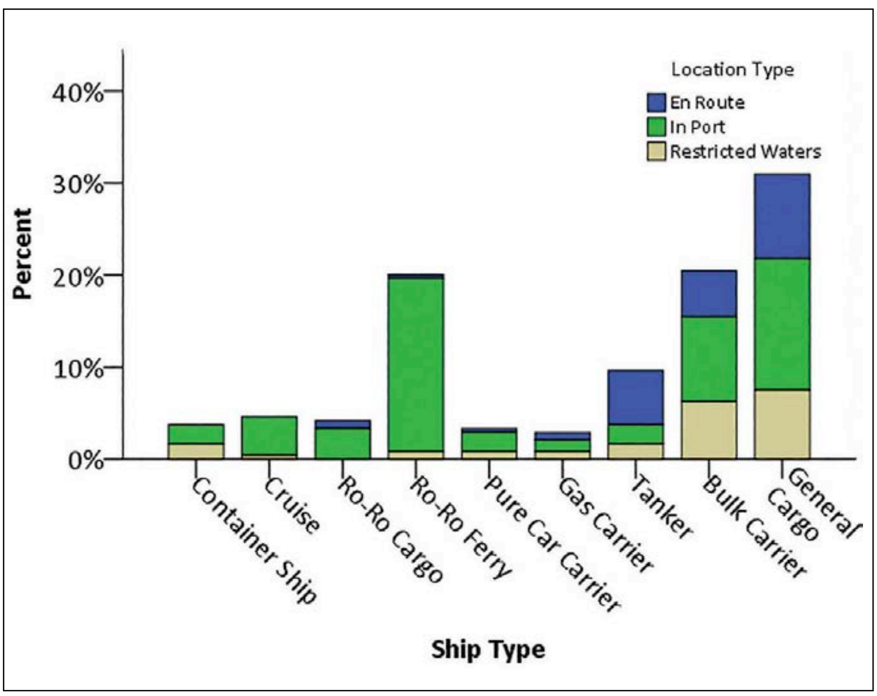


Figure 2: Percentage of ship types engaged in navigational accidents in the presence of adverse weather conditions by accident location, project SHOPERA

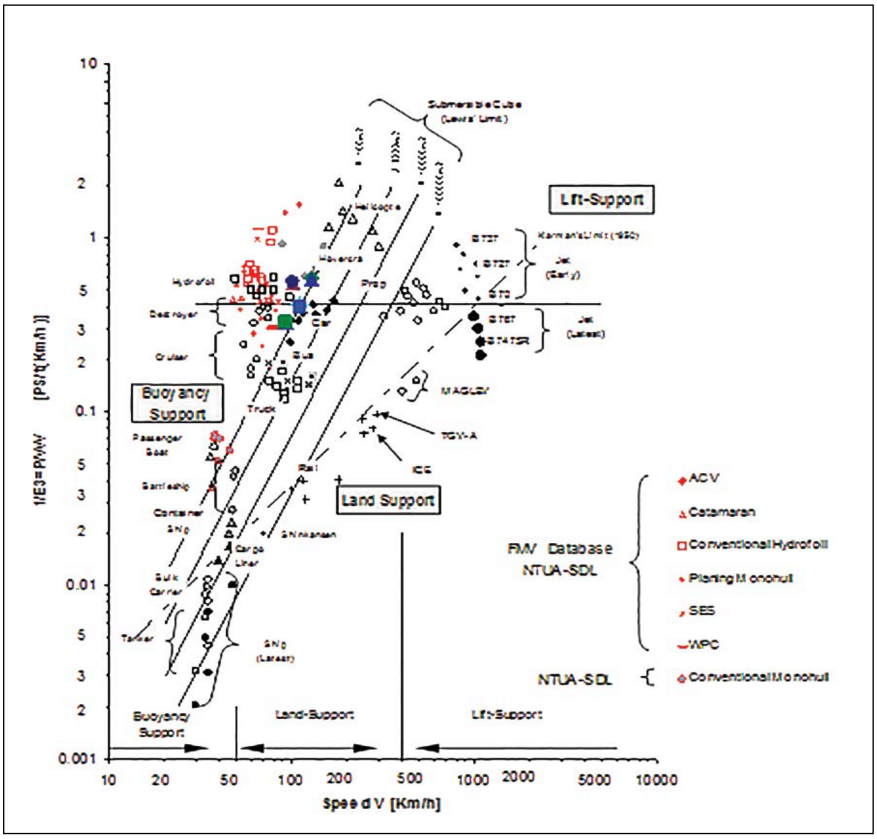


Figure 3: Reciprocal transport efficiency of alternative modes of transport

worsen the statistics of collision accidents for some ships, especially of ro-pax ships in port areas, as well as of groundings in adverse weather. As it is clearly shown in Figure 1, that ro-pax vessels exhibit high vulnerability with respect to navigational accidents, particularly contacts, in adverse conditions, almost exclusively in port areas (Figure 2).

The statistics may have been expected, because the manoeuvrability of ships at reduced speed (e.g. during the approach of ports and docking) in restricted areas and under the action of strong winds is especially problematic for ships with large windage areas, which includes ro-pax vessels. This is reinforced by their frequent port calls, which are characteristic of their voyage profile.

This research was originally triggered by a series of partly controversial submissions to IMO referring to the introduction of the EEDI regulations to ro-pax and ro-ro cargo ships.

In the study, which is also addressing issues of safe ship operations in adverse weather conditions, alternative formulations and values are proposed for the disputed exponents of the correction factor for ro-pax, namely $f_{jRo\text{-}Ro}$, which resulted from a regression analysis of a large number of vessels, built between 1990-2012. Derived formulations are compared with the latest IMO developments concerning EEDI and they appear to rather better represent the energy efficiency and environmental impact of the operating ro-pax fleet.

Theoretical background

Ships are built for covering the needs of society through the provision of specific services. These services may be on a commercial (generating profit for the shipowner) or non-commercial (related to public services) basis. Commercial ships carry all types of cargo and provide in fact the largest (by volume of cargo and transport distance in tonne-miles) worldwide transportation work, compared to other modes of transport. When comparing the transport efficiency of marine vehicles with that of alternative modes of transport (land and airborne), it is very useful to employ the well-known *von Karman–Gabrielli* transport efficiency diagram. Figure 3 represents this diagram following a re-plot of Professor *S. Akagi*'s diagram (published in Proc. FAST'91) in terms of the reciprocal transport efficiency, defined as the ratio of the total installed power P in [PS] to the product of the vehicle's weight or ship's displacement W in [tons] times the attainable maximum speed V in [km/h]:

$$\frac{1}{E_3}=\frac{P}{W \cdot V} \quad c \qquad (1)$$

From the comparative graph in Figure 3, it is evident that ships are among all transport modes the most energy efficient transport vehicles; of course, the transportation speed has a tremendous effect on the transport efficiency and the domains of application of the various modes of transport are clearly defined, even though at 'intermediate' speeds several modes of transport may be competitive considering 'door to door' transport services.

The recently introduced EEDI is practically an extension of the above equation (1), while assuming a certain ratio between ship's deadweight capacity and ship's displacement (weight). Thus, the attained EEDI of a new ship is a measure of ship's energy efficiency in terms of consumed fuel and of associated CO_2 emissions per transportation work expressed in [g/t nm] and is calculated by the following formulation on page 38: (2).

In the numerator of equation (2), f_j is a correction factor that accounts for ship specific design elements; in the case of ro-pax ships, it is replaced by the ship design correction factor $f_{jRo\text{-}Ro}$ which is defined below. The subscripts $()_{ME(i)}$ and $()_{AE(i)}$ refer to the main and auxiliary engine(s) respectively. In the numerator of the equation (2), the P corresponds to the power of the main and auxiliary engines, measured in [kW]. The $P_{ME(i)}$ is 75% of the rated installed power (MCR, Maximum Continuous Rating) for each main engine ( )(i). The PAE is the required auxiliary engine power to supply normal maximum sea load including necessary power for propulsion machinery/systems and accommodation, at reference speed V_{ref} [kn].

$$
EEDI_{att}\left[\frac{g}{t\cdot nm}\right] = \frac{\left[\begin{array}{l}\left(\Pi_{j=1}^{n} f_j\right)\left(\sum_{i=1}^{nME} P_{ME(i)}C_{FME(i)}SFC_{ME(i)}\right) \\ \quad +\left(P_{AE}C_{FAE}SFC_{AE}\right) \\ \quad +\left(\left(\Pi_{j=1}^{n} f_j\cdot\sum_{i=1}^{nPTI} P_{PTI(i)}-\sum_{i=1}^{n_{eff}} f_{eff(i)}\cdot P_{AEeff(i)}\right)C_{AE}SFC_{AE}\right) \\ \quad -\left(\sum_{i=1}^{n_{eff}} f_{eff(i)}\cdot P_{eff(i)}C_{FME}SFC_{ME}\right)\end{array}\right]}{f_i\cdot f_c\cdot f_l\cdot Capacity\cdot f_w\cdot V_{ref}} \tag{2}
$$

In the cases where shaft motor(s) are installed, the $P_{PTI(i)}$ is 75% of the rated power consumption of each shaft motor divided by the weighted average efficiency of the generator(s). The $P_{eff(i)}$ is the output of the innovative mechanical energy efficient technology for propulsion at 75% main engine power. The P_{AEeff} (i) is the auxiliary power reduction due to innovative electrical energy efficient technology measured at PME(i). The C_F is a non-dimensional conversion factor between fuel consumption measured in [g] and CO_2 emission also measured in [g] based on carbon content. The SFC in equation (2) stands for the certified Specific Fuel Consumption, measured in [g/kWh], of the engines. The $f_{eff(i)}$ is the availability factor of each innovative energy efficiency technology.

In the denominator of equation (2), the fi is the capacity factor for any technical/regulatory limitation on capacity and equals to 1.0 (one) for ro-pax. The f_c is the cubic capacity correction factor, which for ro-pax is replaced by f_{cRoPax}, as is explained later. The capacity is defined as the deadweight (DWT) for ro-pax, even though ro-pax vessels are better characterised by their gross tonnage (GT) as volume carriers. Finally, the fw is a non-dimensional coefficient indicating the decrease of speed in representative sea conditions of wave height, wave frequency and wind speed (factor accounting for the added resistance and increased powering of the ship operating in realistic environmental conditions). It may be evaluated by advanced (in IMO jargon: level 2 or level 3) or simplified (level 1) methods for calculating the added resistance of ships in waves.

Correction factors for ro-ro passenger ships

Ro-pax vessels dispose in general a large diversity in their mission profile, as well as in terms of design and operational conditions. Their relatively high demand for installed power, in combination with the enhanced service speed is an integral part of their service to the society, and leads to a wide EEDI scatter. This, in turn, requires the introduction of suitable correction factors in order to get a proper required EEDI reference line for this ship type. That was the reason that these ships were excluded from the implementation of the required EEDI in the first phase. It was not until 2014 when the method to include ro-pax vessels into the IMO energy efficiency regulatory framework was finally adopted.

In order to enable the introduction of ro-pax into the EEDI framework, the capacity correction factor fcRoPax and the ship design correction factor fjRoRo were introduced to the IMO in December 2012 following a joint proposal from the Swedish and German delegations. The cubic capacity correction factor fcRoPax, which is applicable only to ro-pax exhibiting a (DWT/GT) ratio of less than that of the fleet average, namely approximately 0.25, is defined as follows:

$$
f_{cRoPax} = \left(\frac{\left(\frac{DWT}{GT}\right)}{0.25}\right)^{-0.8} \tag{3}
$$

Where GT is the Gross Tonnage in accordance to regulation 3 of the reference.

Finally, in equation (2), the f_j for ro-pax is calculated as follows:

$$
f_{jRoRo} = \frac{1}{\left(F_{nL}^{\alpha}\times\left(\frac{L_{pp}}{B}\right)^{\beta}\times\left(\frac{B}{T}\right)^{\gamma}\times\left(\frac{L_{pp}}{\nabla^{\frac{1}{3}}}\right)^{\delta}\right.} \tag{4}
$$

Where L_{pp} is the ship's length between perpendiculars [m], B is the ship's breadth [m], T is the ship's draught [m], ∇ is ship's volumetric displacement [m^3] and F_{nL} is the Froude number defined as:

$$
Fn_L = \frac{0,5144\times V_{ref}}{\sqrt{g\times L_{pp}}} \tag{5}
$$

Where g is the gravitational acceleration [= 9.81m/sec^2] and V_{ref} is ship' s reference speed [kn]. The exponents alpha (α), beta (β), gamma (γ) & delta (δ) need to be rationally determined.

In case the correction factor f_{jRoRo} >1, then f_{jRoRo}=1. It is noted that the correction factor f_{cRoPax} is used in the calculation of the attained EEDI, but was also used in the development of the EEDI reference line.

Ship Design Variable

The denominator of the fraction in equation (2) is defined as a Ship Design Variable SDV. That is:

$$
SDV = F_{nL}^{\alpha}\times\left(\frac{L_{pp}}{B}\right)^{\beta}\times\left(\frac{B}{T}\right)^{\gamma}\times\left(\frac{L_{pp}}{\nabla^{\frac{1}{3}}}\right)^{\delta} \tag{6}
$$

So the equation (4) can also be written as follows:

$$
f_{jRoRo} = \frac{1}{\left(F_{nL}^{\alpha}\times\left(\frac{L_{pp}}{B}\right)^{\beta}\times\left(\frac{B}{T}\right)^{\gamma}\times\left(\frac{L_{pp}}{\nabla^{\frac{1}{3}}}\right)^{\delta}\right)} = \frac{1}{SDV}
$$

The SDV is the product of the Froude number (FnL)α and the non-dimensional ratios, all of which have a significant influence on the ship-power performance.

Estimated EEDI value

The estimated index value for each ro-pax sample ship is calculated as:

$$
Estimated\ EEDI\ Index\ Value = \frac{3.1144\cdot(f_{jRoRo}\cdot 190\cdot\sum P_{MEi}+215\cdot P_{AE}}{f_{cRoPax}\cdot Capacity\cdot V_{ref}} \tag{7}
$$

The auxiliary power PAE for ro-pax sample ships is calculated as:

$$
P_{AE} = 0.866\cdot GT^{0.732} \tag{8}
$$

Derivation of relationships for EEDI

For all new ships above 400GT, built after 1 January 2016 (the effective date for the EEDI regulations for ro-ro vessels), the attained EEDI needs to be estimated and it should be equal to, or less than, the required EEDI, which is set by IMO. The attained EEDI is the actually calculated and properly verified EEDI value for an individual ship, whereas the required EEDI is the maximum allowable value of the attained EEDI set by regulation. The required EEDI is expressed as:

$$Attained\ EEDI \leq Required\ EEDI \leq a \cdot Capacity^{-c} \qquad (9)$$

Where the capacity for ro-pax refers to a ship's deadweight and the constants (a) and (c) are given in Table 1:

Table 1: Required EEDI calculation

Shiptype	a	c
Ro-Ro Passenger (ro-pax)	752.16	0.381

Hence, noting that the largest influence on the emitted CO_2 on their numerator is mostly coming from main engine power PME, and based on the assumption that the capacity (meaning the DWT for these ships) is linearly proportional to the ship's displacement volume, the equation (9) is reformulated to the following expression for the main engine power P_{ME} : (10)

$$P_{ME} \leq Const. \cdot L_{PP}^{\frac{1}{2}} \cdot F_{nL}^{(\alpha+1)} \cdot \left(\frac{L_{PP}}{B}\right)^{\beta} \cdot \left(\frac{B}{T}\right)^{\gamma} \cdot \left(\frac{L_{PP}}{\nabla^{\frac{1}{3}}}\right)^{\delta}$$

The relation between the main engine power PME (=75% MCR), and the relevant ship particulars, as expressed on the right-hand side in the equation (10) is investigated. The right-hand side of the equation (10) is introduced as the Main Engine Power Ship Design Variable SDVPME: (11)

$$SDV_{PME} = L_{PP}^{\frac{1}{2}} \cdot F_{nL}^{(\alpha+1)} \cdot \left(\frac{L_{PP}}{B}\right)^{\beta} \cdot \left(\frac{B}{T}\right)^{\gamma} \cdot \left(\frac{L_{PP}}{\nabla^{\frac{1}{3}}}\right)^{\delta} \cdot \nabla^{\varepsilon}$$

Methodological approach

The aim of our study was the calculation of suitable values for the exponents α, β, γ, δ and ε of the SDV (as expressed in equation (6)) and the Main Engine Power Ship Design Variable SDVPME (as expressed in equation (11)). The study was conducted by using the semi-empirical Holtrop's method for the estimation of the powering of a rich sample of ro-pax ships and Normand's relational method for the calculation of suitable values for the exponents α, *β*, *γ*, *δ* and *ε*.

Sample presentation

The statistical ro-pax sample consists of 181 ships (112 ships built between 1990-1999, and 69 ships built between 2000-2012) over 400GT. The noted IHS Fairplay database service speed is used as reference speed Vref and likewise the IHSF database field giving ship's total installed main power is used for the identification of *Maximum Continuous Rating* $MCR_{ME(i)}$.

Analysis, results and discussions

The obtained exponent values for equation (6) and equation (11) vary significantly from the exponent values that have been adopted by IMO. At first, we recall the definition of the EEDI reference/boundary line, which should not be exceeded:

$$Max\ (EEDI): Reference\ line\ value = a \cdot (100\%\ DWT)^{-c} \qquad (21)$$

Where the constants (a) and (c) are based on data provided in the aforementioned Table 1.

It is noted that in the original Swedish/German proposal to IMO, it was supposed

Figure 4: Ro-pax ships under study: Year built

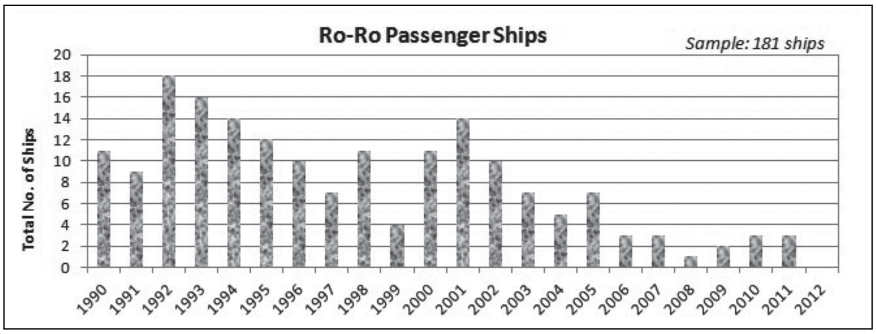


Figure 5: Ro-pax ships under study: L/B, B/T & L/Vol^(1/3)

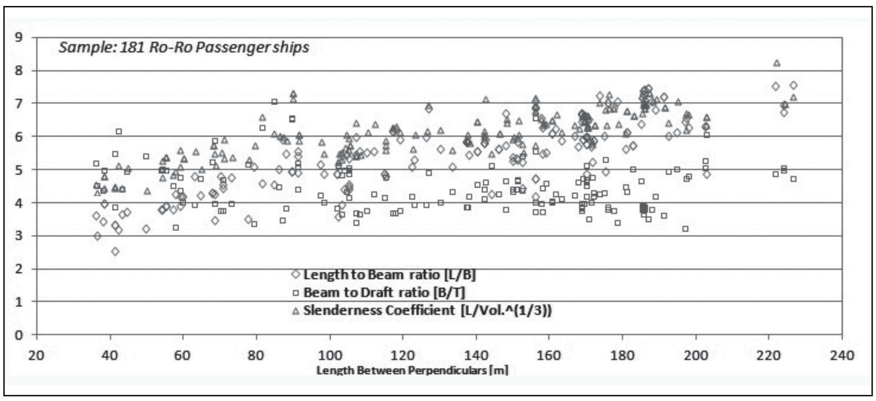
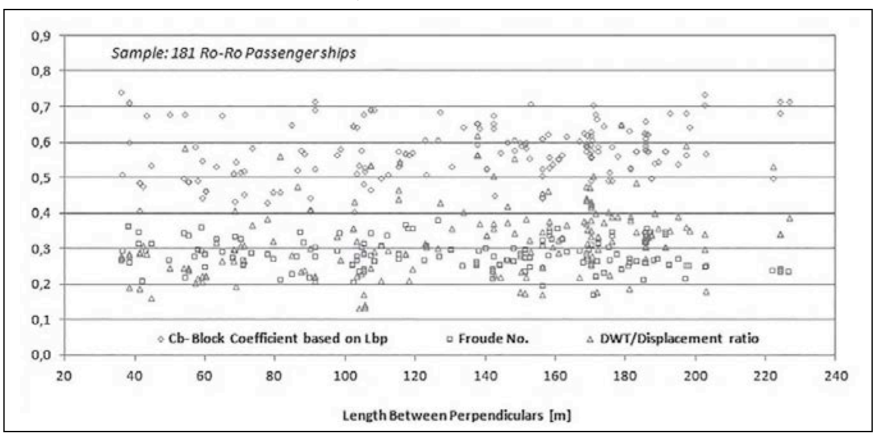


Figure 6: Ro-pax ships under study: c_b, Fn & DWT/Displacement



that there is a proportional function between main engine power P_{ME} and the mathematical expression on the right of the equation (10). Therefore, in our study, we calculated the sought exponent values for the case of *linearity* between main engine power P_{ME} and Main Engine Power Ship Design Variable SDV_{PME}, as well as in case of a non-linear modelling.

The results of both approaches (non-linear approach and linear approach) are presented in Table 2. Also, the adopted IMO values are listed in the first column, which are based on a linear relationship between P_{ME} and SDV_{PME}. It is noted that according to IMO the value of the exponent ε of the ship's volumetric displacement follows the Swedish/German proposal MEPC 64/4/14, while the exponents α, β, γ and δ are according to final Resolution MEPC 245(66).

Both our approaches resulted in an opposite sign for the values of the exponent *δ* of the slenderness coefficient, compared to the corresponding IMO value. Our study concluded that this value is negative, which is also in agreement with the physics of the problem in hand, namely that a high slenderness coefficient leads to a reduction of the intensity of the generated ship-bound waves, and consequently of ship's wave resistance and of associated powering, which is a significant part of the overall powering for ro-pax ships, operating at a relatively high Froude number.

As far as the other four exponents α, *β*, *γ* and ε are concerned, their sign is positive; however, there are significant differences in their values; for instance, the value of exponent beta *β*, according to IMO equals 0.75 and is almost three times smaller than the value of 2.00, which was calculated by the present linear approach. The corresponding values according to Hans Otto Kristensen, the head of the maritime centre at the Technical University of Denmark, are even higher.

Figure 7 clearly shows that the correlation factor of the derived formulas in this study are higher (even though in the range of 1-2%) than the corresponding one of the IMO adopted values, when applied to the same sample of ships under study, they, therefore, represent the properties of the currently operating ro-pax fleet much better.

Figure 8 shows an improved fitting in the proposed reference line according to the present linear approach of our study. The curve of the required EEDI original (where 'original' refers to the option without the effect of the correction factor f_{jRoRo}) is also plotted. Some comparative estimated index values for a sample of ships and the corresponding required EEDI original, EEDI according to MEPC 245 (66) and EEDI according to the linear approach of the present study are presented in Table 3.

From the comparisons, it is evident that:

- The introduced correction factor f_{jRoRo} reduces significantly the calculated EEDI value, compared to the EEDI original and the EEDI MEPC 245/66 formulas.
- The scatter of the estimated index values is also greatly reduced and appears to better represent the powering of ships with similar design characteristics.
- The dependence of EEDI on ship's size/capacity is also smoother and generally confirms the trend of decreasing EEDI with increasing ship size/capacity.
- The herein proposed EEDI framework leads in all sample ship cases to lower EEDI values.

Exponent values	acc. to IMO	present study Non-Linear approach	present study Linear approach
α	2.50	2.79	2.00
β	0.75	1.97	2.00
γ	0.75	1.40	1.50
δ	1.00	-2.07	-1.00
ε	0.567	0.93	0.567

Table 2: Exponent values for ro-pax

Conclusions

The introduction of EEDI to ro-pax ships has been strongly debated at IMO. Besides the large diversity of ro-pax designs, which is typical to this ship type, the observed significant spread of data of existing ships, which were used by the EEDI reference line's developers, is attributed to the processing of inaccurate speed / powering information and of improper parametric relationships between basic ship characteristics and properties.

The present study proposes alternative, improved values for the exponents of the correction factor f_{jRoRo} pertaining to ro-pax vessels in the EEDI calculation. A non-linear relationship between the main engine power P_{ME} and the Main Engine Power Ship Design Variable SDV_{PME} proved superior to others and of higher correlation with respect to the representativeness of the employed ship data sample. Our linear approach, developed in parallel in the present study, led as well to a higher (even marginally) correlation coefficient, when calculating the required EEDI reference line for a large sample of ships, compared to the corresponding one adopted by IMO. The observed diversity in the quality of fitting and the variation of the exponent values raises some justified questions regarding the maturity of the EEDI reference lines for ro-pax vessels adopted so far by IMO.

Presently adopted EEDI reference lines for the ro-pax ships (as for some other ship types) are currently being assessed with respect to the minimum powering and manoeuvrability requirements in adverse weather conditions by the EU funded project SHOPERA (2013-2016) and in collaboration with other international project teams. Obtained results are planned to be submitted for consideration to IMO-MEPC70 in October 2016. *NA*

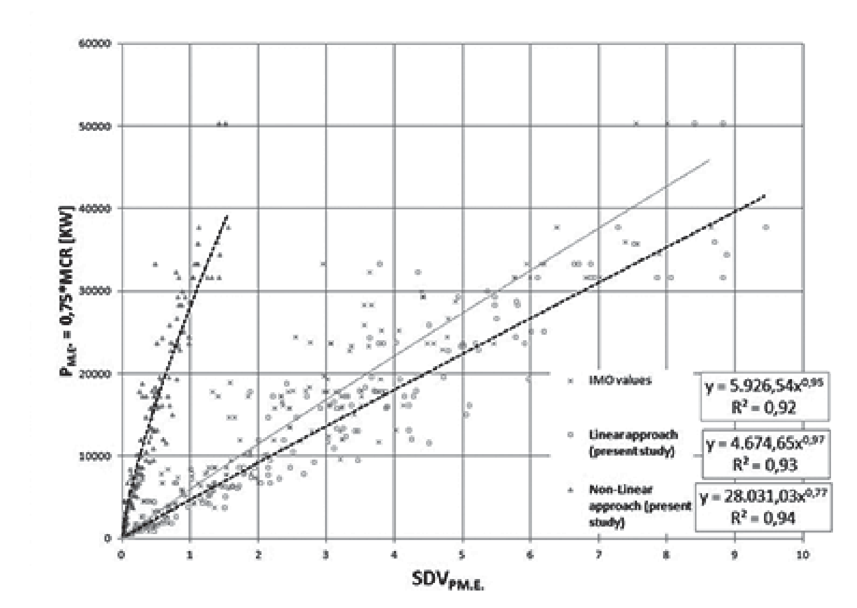


Figure 7: Ro-pax ships under study: PME as a function of SDVPME

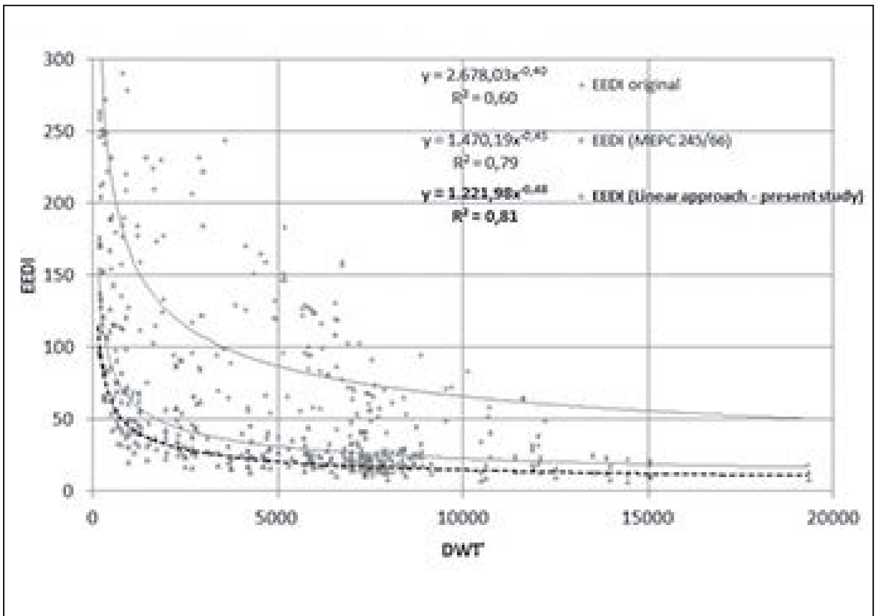


Figure 8: EEDI reference lines for ro-pax ships under study

DWT_{cor} [t]	L_{BP} [m]	Beam [m]	Draft [m]	V_{ref} [kn]	EEDI original	EEDI (MEPC 245/66)	EEDI (Linear approach - present study)
870	79.20	15.50	4.60	15.00	221.20	121.23	100.37
1258	110.00	19.80	5.26	20.00	159.36	55.60	44.74
2738	101.83	20.72	5.40	16.00	66.28	44.54	26.60
3057	123.00	23.00	5.81	21.00	117.59	37.95	28.76
3723	142.30	23.90	5.15	20.50	124.82	24.15	16.39
8058	168.70	26.00	6.50	22.80	62.63	22.09	15.33
11826	180.66	31.93	7.12	21.00	151.69	32.53	20.01
12465	221.75	29.32	6.00	22.00	52.35	16.81	10.72
15011	224.00	32.02	6.40	22.00	65.93	21.46	11.75

Table 3: Estimated EEDI Index values for ro-pax

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Shipping's 4th revolution

Where have we got to with smart shipping? There's lots of interest, but the question "what does it really mean?" is still open for debate. Is it about better gadgets, or a better way of managing sea transport? Martin Stopford analyses the new skills required in the burgeoning Smart Ship reality

The smart shipping debate has drawn attention to major shortcomings in today's sea transport system. Shipping cycles are fascinating, but the world economy needs better transport management.

The current investment super-cycle illustrates the problem – it is an inefficient, disruptive and primitive way of planning transport capacity. The fact that the average tanker delivered half as much cargo in 2015 as it did in 1973 illustrates another aspect of the problem – the need for greater awareness of value added.[1] Today's rapidly improving information & communications technology (ICT) offers a better way to manage many businesses and sea transport is no exception.[2]

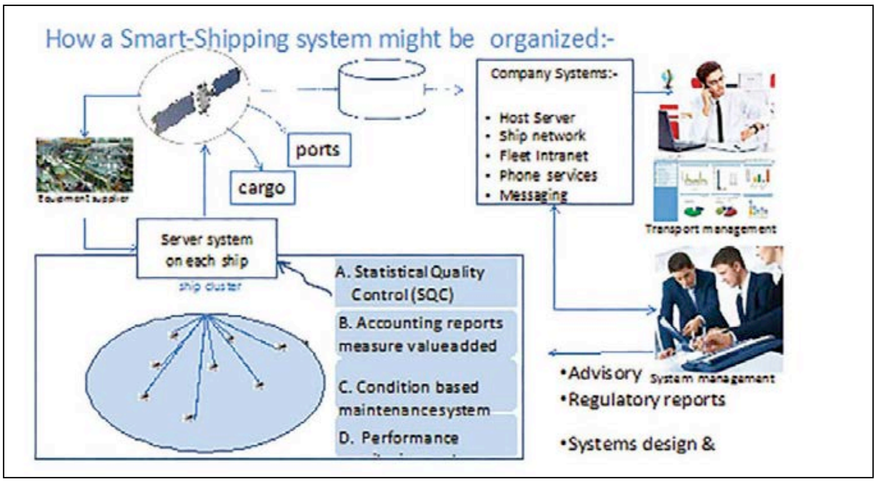

Figure 1: Capturing unused information can be used to improve transport operations

Three challenges

Looking ahead, there are three challenges. Firstly, the industry must transport more cargo with a smaller carbon footprint. Secondly, the global transport network is changing as the non-OECD countries increase their share of sea transport (non-OECD cargo overtook OECD imports five years ago). New global BtoB (business-to-business) trading platforms will need faster, more efficient maritime transport. Thirdly, conventional naval architecture and marine engineering are mature disciplines and can contribute little to addressing these problems.

The goal for meeting these challenges should be better management of global transport. The future is not about steel structures, it's about using the new wave of information and communication technology (ICT) to manage transport more efficiently. The "digital thread" shown in Figure 1 illustrates how this can capture unused information and use it to improve transport operations. The new maritime mission should be to manage transport to add value by delivering cargo more efficiently.

In today's world information is more powerful than steel and energy. The new approach illustrated in Figure 1 uses ICT to manage a fleet of ships as an integrated business producing transport. It's the same basic philosophy car manufacturers like BMW have used to improve the efficiency and flexibility of manufacturing motor cars. The end product is better use of the ships; more efficient use of energy; faster and more reliable cargo transport; and greater economic value added. ICT can be

2016 THE SMART SHIPPING TOOLBOX

1. Satellite communication:
New INMARSAT Kaband global systems (99% reliable) broadband data to be collected, processed & beamed ashore. Telephone too.

2. Telematics:
"Sensors" generate digital information about equipment & ship -cheaper and better than ever.

3.Data Storage:
The cloud provides storage for data generated by sensors. Analyse "Big Data" to improve performance.

4.Smart phone-style apps:
To do specific jobs without big computer systems & management information.

5.Information systems:
Management know exactly what's going on and performance levels.

6.Automation:
Feedback loops allow automation of many tasks (navigation, maintenance, operations etc).

used to make all of these goals measurable and achievable.[3]

The mature digital toolbox

The smart shipping 'toolbox' contains six types of ICT technology, which are increasingly viable (Box 1). This technology improves every year. To maritime historians the development model looks rather like the evolution of steam engines of the 19th century. Steam engines started the century clunky and primitive, and gradually became massively efficient and reliable. It took about 40 years.

Who knows how long it will take ICT technology to evolve? Doing this sort of thing is fraught with difficulty in an industry run by about 8,000 companies managing a fleet of 40,000 cargo ships. Major support will be needed from specialist architects and engineers to develop systems and apps, and to establish robust protocols.

At the heart of this evolving technology are satellite communications. Inmarsat launched its new Fleet Xpress system in March 2016. This Ka band service is a major step forward, offering broadband communication, backed up by the slow, but robust, L band system.

Communications technology takes time to develop, and business plans can anticipate an improvement in communications and a reduction in costs – again the analogy with cables in the 19th century is persuasive. To begin with they were massively expensive, but over 40 years the technology improved and the costs fell.

Over the last year it has become clear that the focus of smart shipping is not just on ICT technology. It is about using ICT technology to introduce management and personnel systems that make the transport system work better. Systems like condition based maintenance provide a working example of the changes that become possible when a fleet of ships is managed as a single production unit.

Action programme

Other industries are already using this technology – none of it is new. But today's speculative shipping model with its super slim overheads and tight margins presents a daunting obstacle to progress. Even more troubling is the limited participation by cargo owners in the transport business today. For example, 50 years ago the oil companies were intimately involved in planning oil transport and logistics, and the result was near-optimum transport performance.

The maritime industry is going to need a great deal of professional support to make this work. Professional courses, training and consultancy will be needed, and the professionals who provide them will need new skills. *NA*

Reference

1. In 1973 the average tanker delivered 49,000 tonmiles of cargo per deadweight. In 2015 the average tanker delivered 24,300 tonmiles per dwt.
2. McKinsey Global Institute The Internet of Things: Mapping The value Beyond the Hype June 2016
3. Condition based maintenance is an example which is available today but not widely used

Big Data and IoT in shipping

NYK Line operates more than 800 ships, from bulk carriers, containerships, car carriers, and tankers to gas carriers. Monohakobi Technology Institute is a subsidiary company 100% owned by NYK Line, and its mission is to conduct technical research into shipping

NYK and MTI (Monohakobi Technology Institute) started R&D on a vessel performance management system called SIMS (Ship Information Management System) in 2008 to reduce CO_2 emissions and fuel oil consumption in the NYK fleet. MTI has been working to support ship operations in each business segment by utilising data collected by SIMS.

We consider our efforts with SIMS a significant case study of Big Data and IoT (the Internet of Things) in shipping and would like to share our view of Big Data and IoT in shipping.

The term Big Data was originally used to describe the situation when the size of computer memory or a hard disk is too small to store a large volume of data, such as science visualisation data. It was then regarded as an advanced data-management technique to utilise a large volume and variety of data to make additional values, such as increasing sales by personalised recommendations based on machine learning of past transaction data.[1] Nowadays, according to technical advances of cheaper online data storage and data-processing platforms for

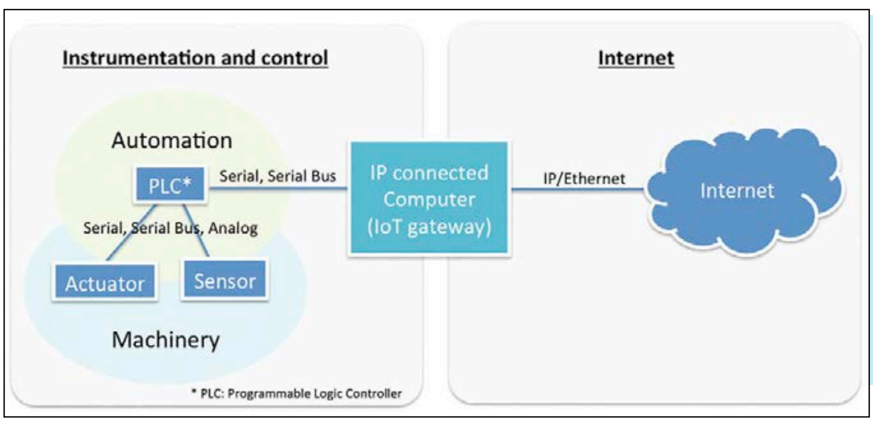

Figure 1: A conceptual scheme of IoT, the Internet of Things

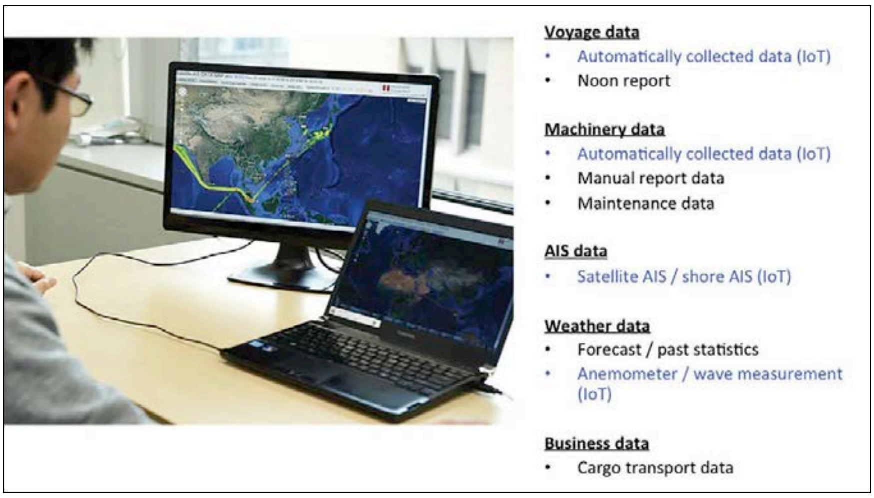

Figure 2: Example sources of Big Data in shipping

non-programmers, many companies are making efforts to turn their data into values, and some have successfully implemented big data into their business processes.

Recently the term IoT also attracted a lot of attention. Figure 1 shows a concept of IoT where the world of conventional automation and instrumentation is connected to the Internet via IP-connected computers. IoT provides transparency of the field sensor data to the users via the Internet. Many manufacturers of industrial products are trying to create new services by using sensor data from their products. Examples of applications based on IoT data include preventive maintenance based on condition-monitoring data, and user service assistance by telemetry (remote-monitoring) data. Of course, security is another very important aspect of IoT.

Big Data and IoT in shipping

Ships have a variety of sensors for forming an automation system and integrated control system, such as a navigation system, a propulsion and power plant operation system, and a cargo control system. Conventionally these sensor data are in closed loops aboard the vessel; however, in line with reduced data-transferring costs and faster satellite communications in the last decade, data sharing between ship and shore on continuous data links has become realistic.

In addition to the sensor data, shipping companies have varieties of unstructured data such as voyage information, performance data, maintenance records, cargo information, and incident records. Weather data is also an important source as voyage route selection, service planning, and ship performance are greatly affected by weather. Originally each data set exists for a specific business purpose, but from the Big Data viewpoint these data may have the potential to improve and optimise shipping companies' operations and businesses.

Another source of ship IoT data is AIS (Automatic Identification System). It is the mandated system for all international trading ships over 300 GT to exchange their ship's position, course, speed, and destination over VHF with surrounding vessels and vessel-traffic services. Constellation satellites catch the VHF radio waves, and service providers make that aggregated global ship AIS data available to the public.

Table 1 shows examples of Big Data applications in shipping. Demanded applications differ depending on the roles and functions of users. For instance, ship operators have interests in applications regarding daily or short-term fleet operations and mid- or long-term fleet planning to optimise their operations and services. Fuel saving is an example application.

By contrast, shipowners might have more interest in technical asset management to minimise maintenance fees and downtime, and in newbuildings to have competitive assets in the market. Stakeholders are not limited to shipping companies, but include external industrial partners such as cargo owners, shipyards, manufacturers, class societies, insurance companies, brokers, and others that might have an interest in the data for its potential to improve their businesses and service levels. Each user might have a different view, and thanks to the ease of using data-analysis tools and platforms, application areas will grow.

Data collection and processing

Utilising Big Data in businesses is an organisational process and requires changing the way of working. Figure 3 shows a general view of the Big Data process flow. First, data must be gathered from the target environment. Then, by data analysis and information sharing, data is converted to information. The information must be recognised by the right person at the right time. This situational awareness step is critical because if the right person has the correct situational awareness at the right time, it results in proper decision-making and the right organisational action.

Each step needs different technology or knowledge. For instance, data collection needs technology of sensors and measurements. Data conversion to information might need skill in data analysis and domain engineering. Creating situational awareness needs business knowledge and people in organisations. To support decision-making requires an understanding of an organisation's management. Action needs incentive and motivation in operations.

It requires changes to the ways of working in organisations, and that's the most challenging part of Big Data. In the end, organisations using Big Data must actively keep learning from the data and improving their business processes.

The following is an example implementation of our own data collection. We developed the data-collection system SIMS as our Big Data platform. It consists of an onboard unit and shore data server. Figure 3 shows a conceptual diagram of a SIMS onboard unit. It collects onboard measurement data from existing automation system, VDR (Voyage Data Recorder) and ICS (Integrated Control System). Original data samplings from the VDR occur about every second, and ICS samplings depend on the number of data points, but they usually occur every 10 to 30 seconds. The sampled data is processed inside the SIMS onboard unit, which outputs statistical data such as the average, minimum, maximum, and standard deviation for each data channel. The output data is packed as a compressed text file, and the file is transferred to shore periodically. In

Table 1: Examples of Big Data applications in shipping

Role	Function	Example of Big data application
Ship operator	Operation	• Energy saving operation • Safety operation • Schedule management
	Fleet planning	• Fleet planning • Service planning • Chartering
Ship owner	Technical management	• Safety operation • Condition monitoring and maintenance • Environmental regulation compliance • Hull & propeller cleaning • Retrofit & modification
	New building	• Design optimization

our case, we normally send data every hour, but the time interval is configurable.

Voyage data is taken from electric voyage reports, and that data is integrated with SIMS data at the shore data server.

Because original definitions of data-channel names are not standardised, making shore software work requires that each data-channel name be consistently mapped to a corresponding data-channel name. We developed a standardised codebook for the purpose, and each channel name of each ship is mapped to the codebook. These efforts at data-channel-name standardisation allow users to download data from multiple vessels at the same time and immediately make comparisons between several vessels.

Figure 4 shows the concept of the SIMS platform. Onboard SIMS units collect data from equipment and machinery on ships, and collected data is provided to SIMS' own applications and third-party applications. At the shore side, a SIMS shore data server stores the data and provides requested data to SIMS applications and third-party applications. As the coverage of our expertise and our resources is limited and it could be the case that a user demands further applications of the data, we thought we had better invite third parties who can provide applications to respond to those demands. One example of data sharing on this platform is weather routing.

Weather-routing services require feedback from ships. Normally the feedback is done by manual reports from ships. But use of the SIMS platform enables a weather routing service provider to acquire up-to-the-minute ship information. They can also fine-tune their ship-performance models with an abundance of accurate data. Now we are working with several machinery manufacturers to assist their remote-diagnostics services. By providing onboard data collection and data transfer to shore, they can concentrate on developing data output from their machines and data-analysis functions.

Furuno Electric, a navigational equipment manufacturer and satellite communication provider, now provides the SIMS platform. We rely on their expertise and global network to install and maintain it. We ourselves now focus on SIMS applications, such as ship performance management for ship operators and ship management applications for ship managers.

Performance management

One of the most important Big Data applications regards ship performance management, which is an issue for ship operators or charterers concerned about fuel consumption and its cost to their fleets. It is also very important in terms of reducing CO_2 emissions.

We consider ship performance management an organisational improvement process by using PI (performance indicators) and a performance-monitoring tool. Success also hinges on other essentials, such as the sharing of objectives among related parties, incentive schemes, continuous learning, information sharing, collaboration, and technologies to solve problems.

In the following, a ship performance model and several applications of using performance monitoring data are introduced.

Ship performance model

From a technical point of view, a performance model is essential. Ship propulsive performances are affected by several factors, such as wind, wave, displacement, trim, and conditions of the hull and propeller. Ideally speaking, the latest ship performance of each ship is captured and should enable estimation of speed and power under arbitrary draft, trim, engine RPM, wind, and wave conditions.

Figure 5 shows an example situation where the performance of a containership drops in rough sea conditions, where wind speed

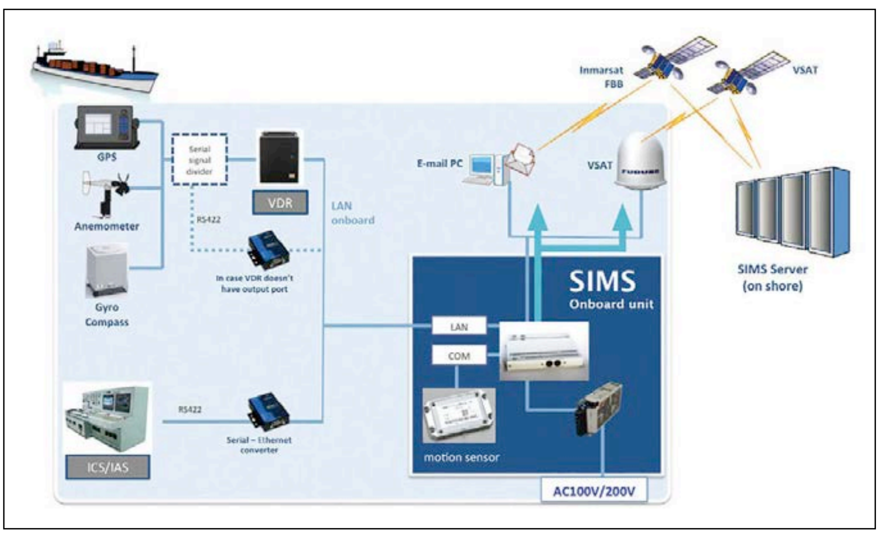

Figure 3: Conceptual diagram of an onboard SIMS unit

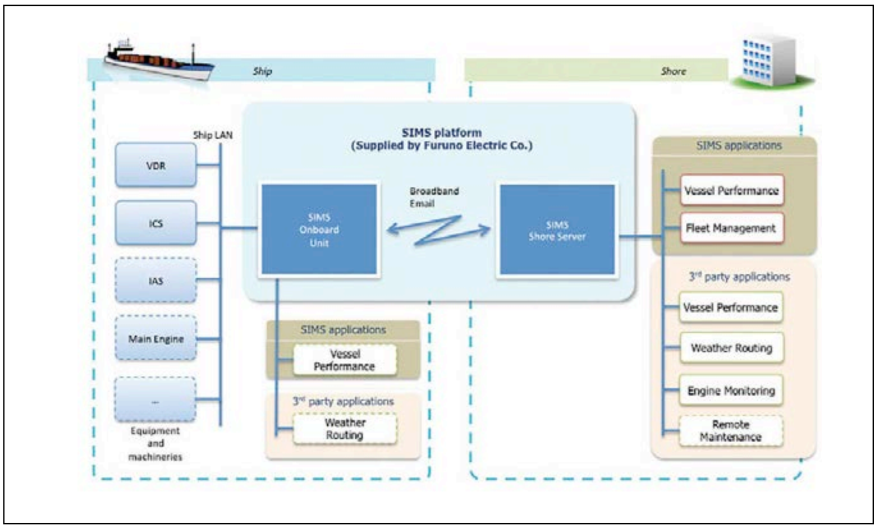

Figure 4: Concept of SIMS open platform

is 20m/s head sea. Engine RPM was 55. Compared to calm sea conditions, this vessel's speed drops from 14kts to 8kts and fuel oil consumption increases from 45tonnes/day to 60tonnes/day.

For estimating the effects of weather, we use the calculation method developed by Tsujimoto et al.[2] The model takes into account the following factors relating to weather:

- Resistance in still water
- Hydrodynamic forces and moment due to drift motion
- Rudder forces and moment
- Wind resistance
- Added resistance in short-crested irregular waves
- Fuel index of main engine

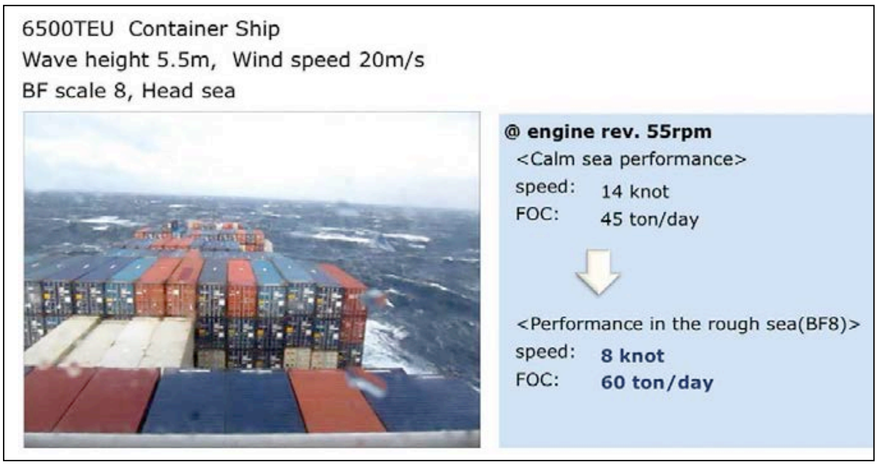

Figure 5: Example of a ship performance drop in rough seas

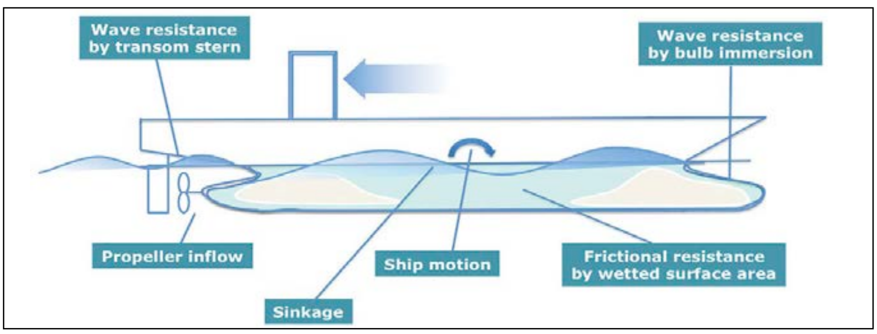

Figure 6: Physical factors affected by draft and trim in seaways

Another factor affecting ship performance is the adhesion of marine growth on a ship's hull and propeller. Larger performance drops may happen during long port stays, drifting, or anchoring, and it should be realised as soon as such a condition change occurs. We have developed a semi-automatic tool to make long-term analyses to estimate hull and propeller performance decline. The input data can be performance-monitoring IoT data or noon report data. By utilising this software even large fleets can be monitored and not miss the right time to clean hulls and propellers.

Draft and trim also affect ship performance. The effects are especially significant for faster ships such as container and ro-ro ships. There are several physical factors affected by draft and trim, as shown in Figure 6. Tank model tests or CFD (computational fluid dynamics) simulation is used to evaluate the major factors involved. The model or CFD test results are discrete and are converted into a continuous model to represent power at arbitrary draft, trim, and speed conditions. If the test results are not available, we make rough estimations of draft and trim effects based on our experiences, and make the continuous model. The model is corrected by measurement data of actual ships.

Ship performance analysis software integrates weather-effect calculations, hull and propeller degrading effects, and draft and trim effects as a ship performance model. Users can check ship performance by changing each parameter, and the model can be corrected by measurement data in the software. It is a supervised machine-learning approach of artificial intelligence, and as data quality increases, model accuracy will be improved.

Optimum weather routing with Big Data

Weather routing service providers recommend voyage plans according to RTA (required time of arrival), latest weather forecasts, and ship performance models. They consider optimum voyage plans in terms of safety, schedule, and fuel oil consumption. They require reports from masters onboard to acquire the latest situations of the ships. Report frequency is normally once per day. If a vessel is equipped with an onboard ship performance monitoring system, it can

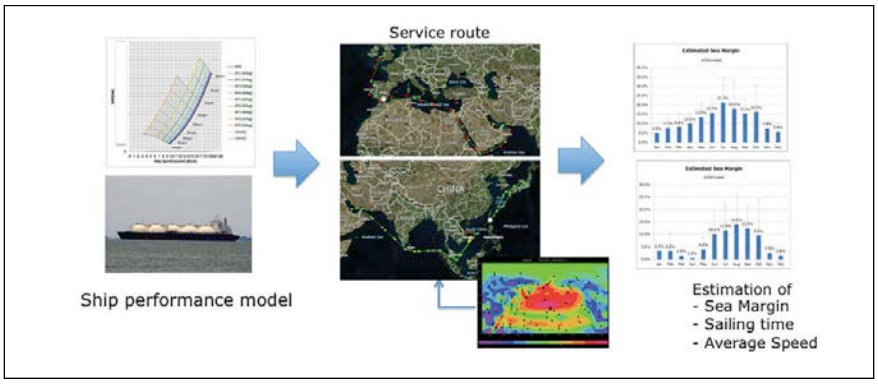

Figure 7: Using the ship performance model and weather statistics for service planning

automatically transmit ship-situation data near real time to shore, and the data feed to weather routing service providers can be utilised in the routing services. The weather routing service providers can compare their estimated speed, fuel consumption, and weather conditions with the actual situation and correct their simulation and update the recommendations. The data improves the service level of weather routing services.

The collected data can also be utilised to update the ship performance model. Normally, weather routing service providers use a statistical regression model regarding ship performance and the accurate performance monitoring data to improve the accuracy of the statistical model.

MTI has also started a trial to utilise the ship performance model, which is described above and includes all factors of ship performance from a shipping company's point of view, as the core model for weather routing services.

Service planning with Big Data

Service planning is another application area of Big Data. Figure 7 shows a conceptual image of ship service planning with Big Data. In this example, vessel routes between the Middle East and Asia are considered. The ship performance model is combined with past weather data. We utilise weather records from the past 10 years and run simulations as if the vessel departs from the departure port every day. As a result, we have data from more than 3,000 virtual voyages and have statistics such as the average and standard deviation of the sea margin or sailing time for each month. We can quantitatively evaluate such seasonal factors and could utilise them in service planning, business contracts, ship operation, or new ship design. Decision-making can become more rational through using the data and the ship performance model.

Operational profile

Once archived, the ships' data can be utilised for a variety of applications. One example is the operational profile. This is an application developed by using a business intelligence (BI) tool. Users can select data-filtering criteria and information is processed; statistics from the data and an operational profile are then shown. Such operational-profile data can be used for ship-operation planning, service planning, paint-coating planning, or new ship design. Thanks to advances in high-level information-visualisation functions and the high usability of recent BI tools, this application itself can be customised by users. Users with business knowledge and experience can by themselves expand the possibility of data use in businesses and operations.

Ship management support

MTI has also developed a Big Data application for supporting ship management that is currently undergoing trials to improve its functionality. Figure 8 shows a dashboard for it. The system's core concept is assisting quick checks of engine plant safety conditions for those managing multiple vessels. It shows several key parameters of engine plants alongside voyage information. Users can see vessel alarms and also set their own rules and criteria for being made aware of events by automatic notification e-mails. These functions are already implemented and are currently in use by several ship management companies.

We also implemented several risk KPI (key performance indicators) to monitor the trouble risks of engine plants. This function is currently under trial to validate its reliability, and we plan to tune the estimation logic developed by expert marine engineers.

We are also inviting several machinery manufacturers to carry out collaborative research to implement such diagnostics functions based on measurement data. This is one instance of our open-platform strategy for working with industry partners, and we are open to further collaborations. *NA*

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Authors: Hideyuki Ando, Ryo Kakuta, and Yoshihiko Maeda from MTI (Monohakobi Technology Institute, NYK Group)

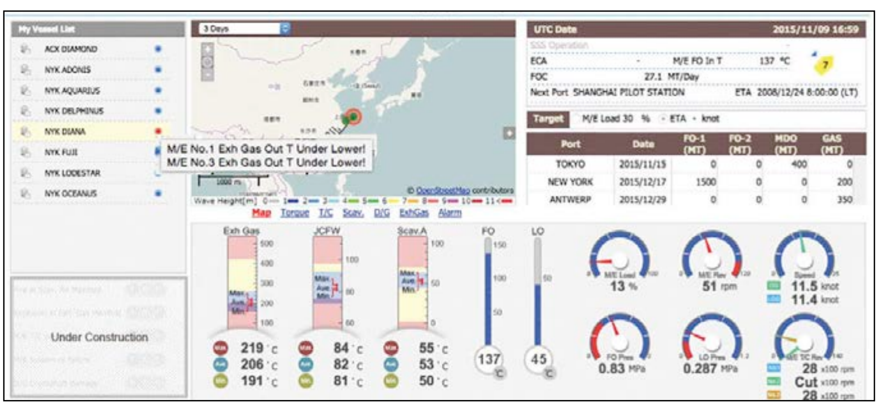


Figure 8: Dashboard for ship management company

There's no level 10

With year one of the Advanced Autonomous Waterborne Applications initiative complete, participating partners revealed their findings at a conference held in Helsinki, Finland, on 5 April

A well-known measure of autonomy, the Sheridan-Verplank scale, ranges from 1-10, but level 10, which marks complete autonomy, is not the aim for autonomous ships currently under development in the Advanced Autonomous Waterborne Applications (AAWA) initiative, says Oskar Levander and Esa Jokioinen of Rolls-Royce.

Instead, humans will continue to play their part and the autonomous vessels under development by Rolls-Royce and its partners will balance remote-control capabilities and varying levels of autonomous function at different operational stages. This will require participation and cognitive work of human operators, but the extent to which humans will participate will vary depending on the type of vessel and the nature of the journey it is taking.

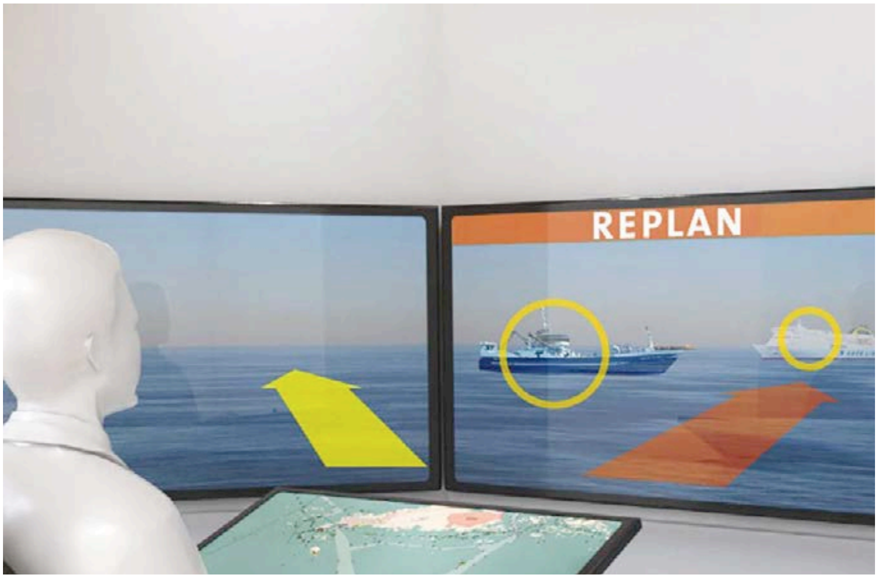


Figure 1: Conceptual view of an "autonomous replan" scenario from an onshore control centre

Synthesising controls

Much of what was revealed at the Helsinki conference focused on the balance being struck in the human-machine interface and the search for the best method for achieving an efficient and safe system of dynamic (shared) control.

Researchers explored the benefit of autonomy at different stages in a ship's operation, concluding that autonomy was better utilised in certain tasks rather than as a single control method.

A shore-based operator will need to decide on operational modes at the start of a voyage, according to Rolls-Royce, setting parameters for their own involvement and the ship's level of autonomy. They will also need to define a fall-back strategy in the event of any hazardous situation, which will demand different strategies depending on the stage of a vessel's journey; congested areas will require more attention than non-congested areas, for example. In this sense, a new pre-planning dimension, unique to the new control method, will have to be added, and the fall-back system will need enough flexibility so that the shore-based operator can modify the parameters and fall-back strategies during a voyage, where directives and scenarios may change and require further human input/intervention.

Setting the parameter of autonomy, or 'ship intelligence', will undoubtedly be key, and Rolls-Royce explored a number of important scenarios where such parameters will define the safe operation of autonomous vessels. Scenarios included an "autonomous evade", "autonomous replan" and an emergency situation, known as "PAN-PAN".

The "autonomous evade" scenario explores the ship's recognition of nearby obstacles and the taking of measures to avoid these obstacles without intervention from the operator. The "autonomous replan" scenario functions in much the same way, but the autonomous ship may need confirmation of any changes it proposes from the operator while attempting to avoid a number of computable obstacles. The "PAN-PAN" situation, however, which presents an emergency, and might include navigating a busy channel where the computer algorithm is not capable of avoiding a series of moving obstacles on its own, will require help from the operator. Such a scenario seems to warrant the remote-control capability Rolls-Royce is seeking to develop, as, at least in the beginning, algorithms will not be capable of dealing with every scenario the shipping industry can throw at them.

As it stands then, the balance between autonomy and remote intervention is yet to be defined, and much of the dialogue and interaction between vessel and on-shore operator will depend on how the parameters of autonomous freedom are set.

Situational awareness

Communication and sensor systems will have to work in harmony to deliver AAWA's vision.

Jonne Poikonen, senior research fellow at the University of Turku's Technology Research Centre, presented how off-ship

Figure 2: The different levels of detail for sensor data transmitted. Operators may be required to translate what a ship 'sees'

communication of sensory data might occur and be presented to on-shore operators.

Rather than a constant stream of 360˚ video, which would place huge pressure on bandwidth limits and connectivity, data transfer will be limited to safety critical information. This, it is hoped, will allow operators to supervise more than one vessel at a time.

In a similar vein, images of obstacles that a ship may perceive and react to, such as a ship on the horizon, could be fed to operators in varying levels of detail that depend on the need and datalink capacity. This can be seen in Figure 2, where a full data image is broken down – for transmission benefits – into one with either segmented features or the most basic object detection data. Poikonen explains that this process of simplification allows for situations where datalink capacity may vary (i.e. due to location, weather, or traffic) and the quantity of transferred data will have to be reduced. Operators will then have to interpret the "imperfect" situational awareness data from the sensors and react accordingly.

The sensor devices to be used onboard are still up for discussion. AAWA makes clear that the technologies to realise remote and autonomous ships already exist, but that the current issue is finding the best way to combine them, ensuring safety and reliability while also making the solution cost-effective.

Fusion of sensors is needed to get reliable object detection and collision avoidance, according to Poikonen, and researchers are trying to borrow as much as possible from the automotive and aeronautical industries so not to reinvent the wheel.

The next step for AAWA is to perform equipment tests with the aim of fusing different sensory technologies in the most beneficial way. This will be helped by AAWA's newly announced technology partner, Brighthouse Intelligence, which will contribute knowledge of wireless communication, digital data transfer and cybersecurity. Markku Sahlström, managing director, Brighthouse Intelligence, says: "Our target when combining forces together with other AAWA partners is to be the technical enabler when bringing remote control activities and safety of the ships to a totally new level."

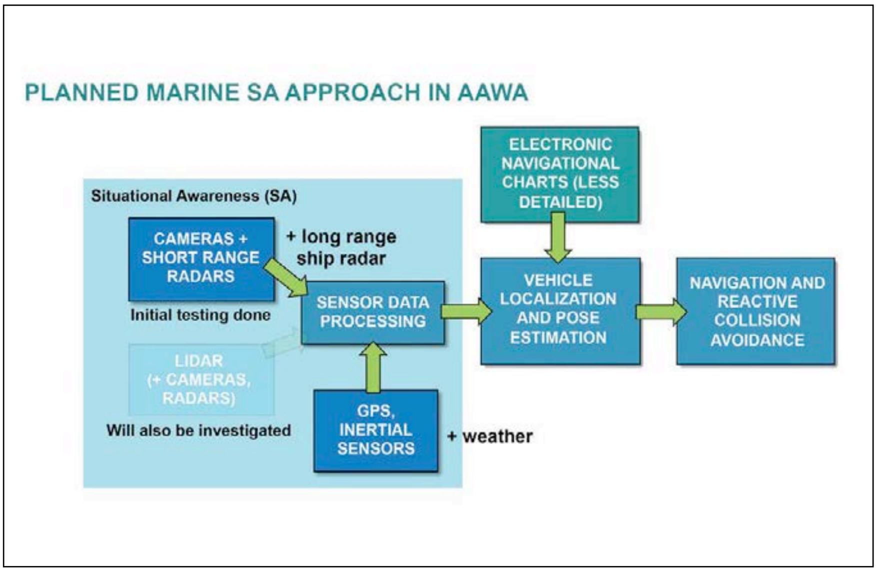
Economic grounds

Levander emphasises that autonomous ships make economic sense, as well as safety and efficiency 'sense', but there is as of yet no estimation, as far as *The Naval Architect* is aware, of the cost of any type of commercial autonomous ship. He does, however, describe a range of savings and benefits, including cuts to manning costs and fuel consumption; the fact that autonomous ships will weigh less, face less air resistance and will be optimised as part of a fleet like never before; and adds that capital costs will also become cheaper in time, although *The Naval Architect* has been led to believe that the first autonomous vessels may be more expensive.

Despite the understandable reluctance to put a figure to future costs, the initiative has always been commercially grounded, according to Rolls-Royce, which says they have been talking with end customers from the beginning. This statement comes as no surprise following the announcement of the first commercial ship operators to take part in the AAWA project.

Ferry operator, Finferries, and dry bulk carrier ESL Shipping, will assist the AAWA initiative as it preliminarily looks into short-range autonomous operations and how autonomous vessels could be utilised over ferry routes and short-sea

Figure 3: How an autonomous ship may interact with its environment



distances. The announced collaboration marks a reality for the project; the first commercial autonomous ships to be built and operated will function within local jurisdictions, before later being adopted for global operation after meeting the more complex regulatory environment overseen by IMO.

Each of the operators has a role to play in the current stage of autonomous ship development. Finferries will take part in a range of sensor tests onboard its 65m ferry, *Stella*, investigating the best combination of different sensory equipment, including visual and thermal cameras, radar, and LIDAR, which will be responsible for safe navigation and collision avoidance of ships that will be juggled between remote and autonomous control.

ESL Shipping will investigate how remote and autonomous vessels might impact the short sea cargo sector. Mikki Koskinen, managing director, ESL Shipping, explains ESL's involvement in the project: "We have seen increasing interest in, and acceptance of, remote and autonomous technologies worldwide across the transport and logistics industries," so "by participating in the AAWA project we will get an early insight into the impact of such transformation on our industry, our business and the lives of the people who work in it."

Legal

Questions of liability remain open, but representatives of AAWA believe that legislation can be changed with political will onboard, building out from a national level to a global level.

Dr Henrik Ringbom, adjunct professor (docent) in maritime law and the law of the sea, Åbo Akademi University Turku/Åbo, Finland (an AAWA partner), elucidates the legal landscape for autonomous and remote-controlled ships:

"The importance of the distinction between remotely operated and completely autonomous lies in that in the former case the ship still has a crew, a master, a watch etc. It is just that they are not onboard the ship. In terms of liability, errors made by a remote controller of the ship need not be treated very differently from errors made by onboard crew members today."

On a completely automated ship that changes; operations are pre-programmed meaning that there is no easily identified master.

Existing maritime legislation does not cover this eventuality and as a result new questions on liability are being raised.

"Will the owner/operator assume liability for any errors linked to the operation of the automated ship, independently of his own fault or involvement and, if so, should that liability be governed and limited according to the same rules as today?" Asks Ringbom. "Or does maritime law have to make space for new liability regimes that specifically accommodate new causal relationships and new players, such as system manufacturers and programmers?"

In all likelihoods, he adds, there will be a range of remote operation that stretches between manual vessel operation and total automation, and most of the automated ships will operate with some form of human intervention, but the level of human control may also vary within different periods of a single voyage.

"At what level of automation can you argue that the master is no longer there? Is a shore-based controller who is only alerted in case of an emergency alarm still on watch and can he perform the duties of a master?" Such enquires raise pertinent issues for the industry.

"The ideal solution is to settle the requirements for automated ship operations at international level, at IMO, alongside the rules for ordinarily crewed ships."

Ringbom finally postulates that "In the end the shift towards unmanned ships might not require very drastic changes to existing legislation, but the specific standards for unmanned operations should be developed jointly to avoid that separate rules are created in different parts of the world."

Remains of the day

AAWA's first year findings brings the potential autonomous future of shipping closer, but its partners do not have or profess to have every solution for facilitating these ships. The time it will take to reach this point is unclear, though Levander firmly believes this is the "dawn of a new era that will see a big change in shipping" and that the 2020 delivery date Rolls-Royce has set for a remotely operated local vessel with reduced crew and remote support will be met.

The AAWA initiative is now moving towards creating a first proof-of-concept demonstrator in 2017. It is continuing to carry out work on the technology that will be needed, understanding new and undiscovered risks posed by unmanned vessels, producing and analysing legal case studies, and expanding stakeholder interviews to establish cost and revenue modes of autonomous operations for different ship types. *NA*

Developing the technical DNA of a Smart Ship

How close is the technology required to deliver Smart Ships? Peter Mantel, managing director of BMT SMART, poses one of the crucial questions as shipping looks to the future

The maritime industry is interested in Smart Ships for a range of reasons, but safety is a key driver. Most accidents at sea are the result of human error, just as they are in cars and planes. If human operators can be replaced by sophisticated sensors and computer systems, autonomous vessels should, in theory, make shipping safer. Cost is also very high on the agenda. Over the past decade the shipping industry has undergone widespread disruption with a 'perfect storm' of unprecedented legislative changes and commercial pressures. The price-softening and lack of demand in the market has led to large numbers of vessels being laid-up, while the steady delivery of new build vessels into an already oversupplied market, coupled with an improving but still generally weak global economy, has put yet more downward pressure on freight and charter rates. In the mid-1990's estimates indicated that the shipping industry's share of global CO_2 emissions could increase 20-30% by 2050. In response, the European Union and the International Maritime Organisation introduced a raft of new regulations including the ship pollution rules.

In tough times and in fierce competition, shipping companies need to optimise all processes. Ships need to be operating at maximum efficiency to ensure they comply with environmental legislation and deliver an optimum level of profitability. The three major costs in ship operations are bunker fuel, crew, and drydocking for maintenance. Bunker fuel costs can often account for up to 60% of total operating costs so the assessment of fuel consumption is fast becoming an integral part of ship owners, operators and charterers' operational strategies, and an understanding of vessel performance management needs to be high on the agenda. Strategies such as slow steaming have proved to be highly successful in certain circumstances with a 30% reduction in speed by a bulk carrier delivering a saving of up to 50% in fuel usage. These longer voyages for ships carrying non-urgent cargo will only compound the issues that the industry has in recruiting and retaining competent crew prepared to spend months away at sea. To deliver both economically viable compliance and commercially acceptable running costs, vessel performance now has to be measured and analysed at a level of detail never previously expected. There are further cost savings available by leveraging the data automatically harvested from the Smart Ship's systems in order to optimise operational costs through prediction and cost-benefit analysis.

Peter Mantel, managing director of BMT SMART

Far from being a theoretical proposition, many of the core technologies required to operate a truly Smart Ship are already in use by shipping lines across the world. In some cases, the integration between technologies is already taking place in order to deliver Fleet and Vessel Performance Management (FVPM).

For the Smart Ship to automatically deliver the operational performance improvements, it needs access to its speed capabilities and the fuel consumption required to achieve those speeds, based on both the vessel's current condition (draft, hull condition, engine condition, propeller condition, etc), as well as the prevailing environmental conditions (sea-state, swell, wind, current, water depth). If data can be provided for multiple vessels within a fleet then the potential benefits can be even greater. The ability to accurately measure, record, analyse and store all of this data is key to the success of the Smart Ship concept. Without it, there is little added value and the Smart Ship becomes little more than a remotely controlled vessel. In order to secure good quality data, BMT SMART^{SERVICES} utilises sensors to accurately measure and collect data from all the different parameters relating to a vessel's energy use and associated performance. Data from the vessel's relevant onboard power, propulsion and navigation systems is collected digitally and aggregated with external environmental data, including wind, waves and current before being processed in real time and analysed against a range of different performance parameters. In addition, traditional noon reports can also be used as a data source.

SMART^{VESSEL} and shore-based diagnostics continuously monitor sensor integrity and adopt a range of approaches rather than relying on single sensor readings to maximise the accuracy of derived performance data. In practice, inevitably, we rely more on the trending of sensor data. For example, the combination of GPS and current data – automatically collected by SMART^{SERVICES} – allows for independent verification of speed through water to ensure maximum accuracy and as a back up to speed log data.

The key to understanding and assessing underlying vessel performance is the ability to filter-out the impact of the environmental conditions. This is only possible in a reliable way by using accurate metocean data to identify the prevailing weather conditions as very few vessels have any onboard measurement for swell or wave height. Changes in the performance of vessels can then be quantified relative to an appropriate baseline such as sea-trial, first 'post dry-dock' round voyage or Charter Party Warranty speed-consumption curve and then ranked in comparison to other vessels in the fleet.

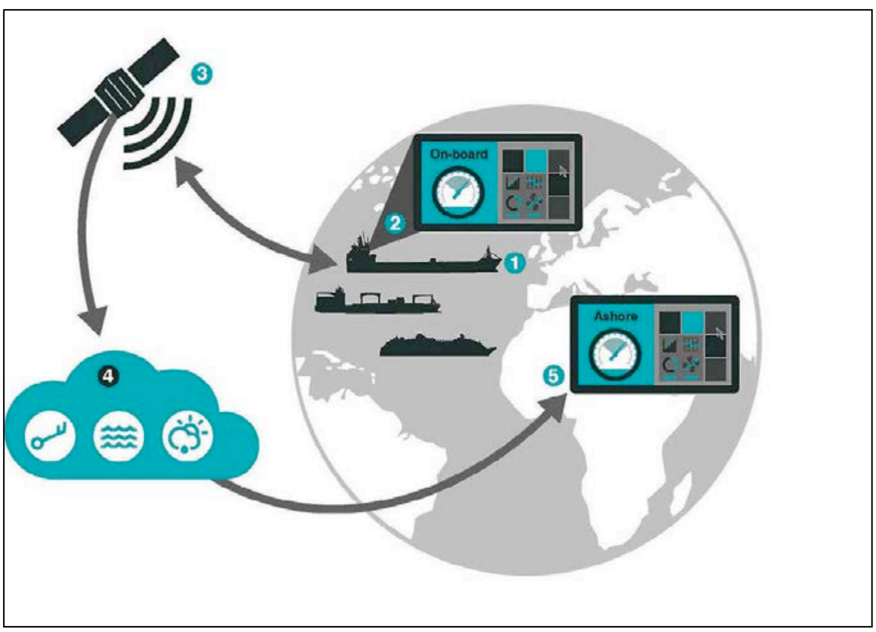
Once the data has been filtered, technical coefficients are calculated, giving the powerful tool of trending isolated performance components. The Fuel Coefficient (overall vessel performance including the engine, propeller and hull), Power Coefficient (overall efficiency of the propeller and hull excluding the engine), Specific Fuel Oil Consumption (SFOC), Propeller and Hull Coefficients isolate the individual components giving the efficiency of each independently. Additionally, a variety of operational KPI's can be automatically calculated from the vessel's data including: Voyage, fuel cost, speed and crew.

Access to large quantities of performance data generated across a fleet of vessels can help identify performance trends that will make Smart Ships even smarter. By understanding how the vessel performance coefficients vary over time, it's possible to provide a pathway to effective, predictive maintenance models. Dry-docking for maintenance and renewal of anti-fouling can be automatically timed to take place just before any rapid drop-off in vessel performance, highlighted by historical and probabilistic efficiency and operational data. The proliferation of data that must be produced, processed, and analysed to make a Smart Ship function effectively and efficiently is far too large for humans or many contemporary systems to deal with, and volumes will just get larger as more functionality is added.

Artificial neural networks (ANNs) are a family of models inspired by biological neural networks (the central nervous systems of animals, in particular the brain) and are used to estimate or approximate functions that may depend on a large number of inputs and are generally unknown. Artificial neural networks are generally presented as systems of interconnected 'neurons' which exchange messages between each other. The connections have numeric weights that can be tuned based on experience, making neural networks adaptive to inputs and capable of learning. Current performance indicators can be improved by using machine learning methods and creating self-improving algorithms.

The quantity and quality of data generated by the Smart Ship will also add value when fed back through an integrated vessel Life Cycle Model (LCM) analysis tool which will accurately model the complete life of the vessel. Models can be developed for all stages of the vessel's life from production, operations, logistics, maintenance, retrofit and recycle/disposal connecting vessel design to all key aspects of a ship's life cycle. By utilising highly accurate in-service data, models can be significantly improved. As the problem involves simultaneous optimisation of several competing objectives changing over time, cutting edge solutions will be employed to solve the time-phased and multi-objective life cycle optimisation problem.

The LCM can be run for specific scenarios, as a simulation of the vessel's whole life. This will enable the user to see the life cycle of the vessel: its operations, its retrofit and its recycling in a simulated way. 'What if' scenarios could be investigated by changing particular parameters, for example: what would be the effect on the through life costs of utilising a different maintenance strategy? What would be the impact of changing fuel type? What influence would recycling/scrappage age have on the design? What is the right vessel for my business? What is the influence



Squaring the circle; how information is exchanged with connected ships of investing in this new technology to improve overall performance? What is the ROI in realistic operating conditions? The real strength of the model will be its ability to optimise the life cycle and consequently the ship design for that life cycle. The model will optimise the net value of vessel or the profit to appraise the cost-benefit economics of the asset. As real performance data is gathered from the authentic operations of the vessel, this will easily be added into the models so that new accurate scenarios can be run on the vessel and enable their use as critical decision making tools. Inclusion of maintenance, obsolescence, retrofitting, logistics and recycling in the LCM and the ability of optimising for multiple objectives can help achieve considerable operational efficiencies.

Another key enabling technology that has been developed by BMT Reliability Consultants and is now being progressively adopted is that of condition based maintenance of equipment (CBM). CBM is a maintenance strategy that monitors the actual condition of the asset to decide what maintenance needs to be done. CBM dictates that maintenance should only be performed when certain indicators show signs of decreasing performance or upcoming failure. Checking plant and machinery for these indicators may include non-invasive measurements, visual inspection, performance data and scheduled tests including vibration monitoring (VM), vibration analysis (VA), thermographic surveys, water fuel and oil sampling. As an example, VM can be used as an 'early warning' system to indicate equipment vibration problems - this could use vibration transducers or motor current monitoring devices all linked into the overall vessel platform management system.

Unlike planned scheduled maintenance (PM), where maintenance is performed based upon predefined scheduled intervals, CBM is performed only after a decrease in the condition of the equipment has been observed. Compared with preventative maintenance, this increases the time between maintenance repairs, because maintenance is done on an as-needed basis.

Using CBM could help to avoid intrusive planned maintenance tasks which can be a source of failures by opening up equipment that is otherwise working very well. Equipment more often fails after a routine maintenance than beforehand. This approach, linked with 3D printing of spare parts onboard ships will fundamentally impact Smart Shipping over the next 10-15 years. This in turn will fundamentally change life cycle costs.

The Smart Ship concept holds huge amounts of potential for the industry with ship modelling, predictive maintenance and operational models all part of the roadmap. Currently, elements of the technology are widely available, however not as a completely integrated turnkey offering. More investment and R&D is required but this is costly and unlikely to take place across the industry without demand for the end product. The shipping industry needs to embrace the concept in order to give manufacturers the confidence to invest more in the necessary R&D, testing and accreditation in real time onboard vessels at sea. *NA*

The human factor in smart shipping

We should welcome technological developments that have the potential to make seafaring safer and reduce isolation, but not forget that the human element must be included too, says David Heindel, chair of the Seafarers' Section of the International Transport Workers' Federation

The questions asked by January's Smart Ships Technology conference are big ones: what do the technologies of the digital age mean for the vessels of the near future? Will they make them safer, self-servicing, cheaper to operate and more fuel efficient? It's to be hoped that alongside these questions will be: what does this mean for those working with and alongside these new technologies?

The first and most important question is how they will affect safety. Arguably, ship design has not yet fully caught up with the potential of data collection (particularly via sensors) in the way that it has been adopted in the aviation industry. Self-diagnostics, automated alarms and post-accident recoverable data stores of the 'black box' kind can help protect lives and the oceans, and are both widely welcomed and already partly in place (or coming).

There is hope that increasing computerisation can support and help safeguard the (increasingly skilled) crew who use it. However, there is a known danger too of ever smaller crews and shrunken watches monitoring more and more monitors, leading, inevitably, to overwork and dangerous exhaustion.

Technology such as e-navigation must be there to safeguard vessels and their crews, and reduce the administrative burden placed upon them. It cannot be used as an excuse for dangerous and unacceptable reductions in crew numbers. These are already dangerously low.

Fatigue is a known factor in human error maritime accidents, and technology must not be one of its causes. The ITF believes fatigue must be tackled through the following safeguards, which can be complemented rather than undermined by new technology:

- Safe crewing levels onboard ship
- Enforcement of maritime regulations on minimum hours of rest and/or maximum hours of work
- New regulations on seafarers' hours of work
- Universal recognition of the right of all seafarers to shore leave
- An onboard safety culture
- Fatigue to be treated as a serious health and safety issue

Dave Heindel, chair of the Seafarers' Section of the International Transport Workers' Federation

Getting the message

One area where maritime technology has proved to be a world leader is communications. The challenges of reliable ship-to-shore communications have been increasingly met in recent decades. It is time now for those capabilities to be shared among ships' human workforces. Research undertaken by and for the ITF and its charity arm the ITF Seafarers' Trust repeatedly flags up lack of onboard internet and mobile phone access as a common concern among seafarers, many of whom are (and soon all of whom will be) drawn from a generation that has grown up on land taking that access for granted. Seafaring is by its nature often lonely and isolated, and carried out far from friends and family for months at a time. It is no longer acceptable that contact with home is often limited to a snatched connection during a rushed visit to a seafarers' centre in the hours in port, that is often a seafarers' only shore leave.

An automated future?

One of the news stories of 2014 was Rolls-Royce's announcement that it was planning to design a new generation of unmanned ships. It's an idea about which the ITF remains sceptical. We believe that, in our lifetimes at least, technology will not be able to safely replace the eyes, ears and thought processes of professional seafarers.

The human element is one of the first lines of defence in the event of machinery failure and the kind of unexpected and sudden changes of conditions in which the world's seas specialise. The dangers posed to the environment by totally unmanned vessels are too easily imagined.

For safety and environmental reasons alone, technology should be a tool for the maritime industry – not the absolute answer.

Man, woman and machine

The possibilities are huge. The future can be bright, so long as we make it so. Safer and better vessels are within reach; centuries of progress in ship design proves it. Our plea is that we do not let the possibilities for change blind us to the need to include the human factor. For the foreseeable future ships will need to be manned and technology must reinforce and support the human role.

Experience tells us that no system is 100% fail-safe, and human intervention is likely to be required, if only when things go wrong. That relationship between crew member and machine must be recognised and built into the development process. It is serving men and women who will be using and running these innovations and will be assisted by them. It is serving men and women who must be consulted as they are planned, developed and put to use. *NA*

Aiming for the future: *Fortitude* points the way for Smart Ships

It is widely recognised that around 80% of marine accidents involve some aspect of human error. In 2013, 54 ships were lost at sea or sank without trace. Team *Fortitude* set out to explore methods for reducing the number of casualties at sea, developing automation that will aid the human part of ship operation

While small autonomous vessels have been in operation for about 20 years, the maritime industry has begun to invest large amounts of money and research in the potential of large autonomous vessels.

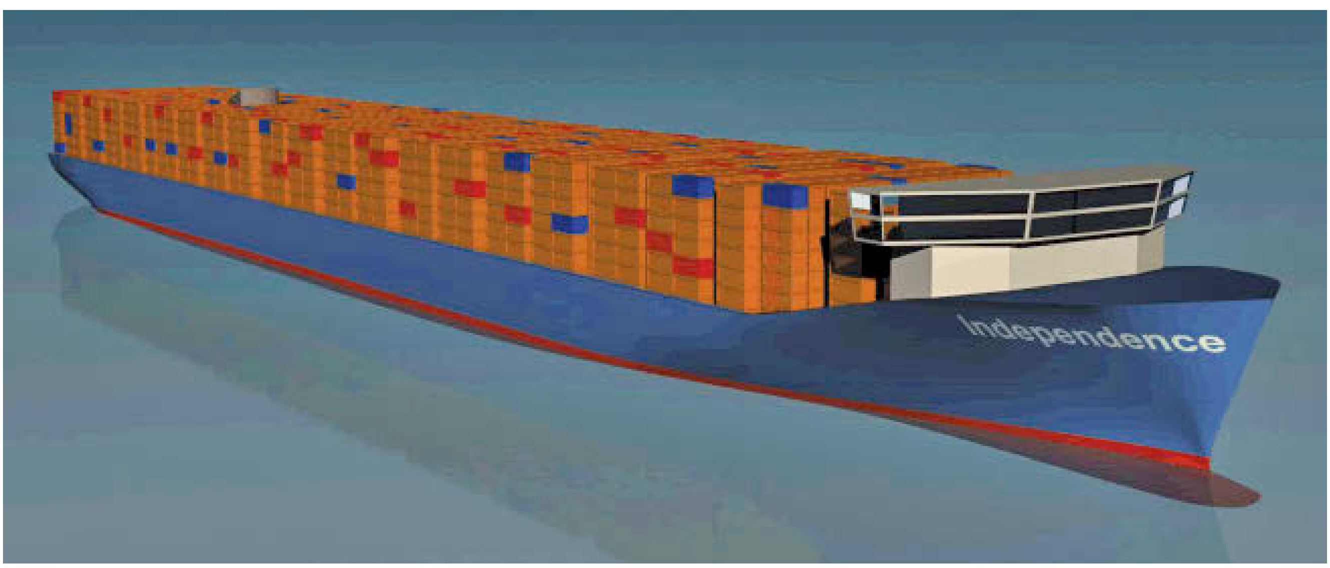
Investigations show that autonomous merchant ships could offer significant economic, environmental and social benefits. The initial aim for Team *Fortitude* was to show proof of this concept for a number of autonomous solutions, and to test some of these concepts practically wherever possible.

Team *Fortitude* decided to tackle this by designing an Autonomous Conceptual Container Vessel (ACCV), *Independence*, to highlight the key similarities and differences between a manned and an unmanned vessel. A container vessel was chosen because the existing industry has places such as the Euromax Terminal in Rotterdam, which is already completely automated. This concept was then used to develop an understanding of some of the barriers to autonomous shipping, while *Fortitude* was utilised as a test platform for navigation, systems management and communications.

Autonomous control of *Fortitude* using a radio link from the 'Shore Based Control Centre'

Originally, the design and construction of *Fortitude* was coordinated by a previous group design project in 2015. Initial testing found that she required a significant amount

The final Autonomous Conceptual Container Vessel (ACCV) *Independence*, a 9,600TEU vessel



of refitting in order to get her working as an autonomous vessel. This refit included work on the resistance and manoeuvrability, the vessel's energy, electrical and control systems, and the design of a bilge system.

The necessity for the refit came from the fact that *Fortitude*, following the tests carried out after build, was not fully operational for the purposes of a test platform. The areas lacking were rudders and fairings, electrical circuits, control systems and power systems. The majority of this work came with ease to Team *Fortitude* because of their naval architecture background, and provided the opportunity to get to know the test platform far better by breaking her down to the absolute basics.

Testing of these changes occurred at the Boldrewood towing tank and at Warsash Maritime Academy's Ship Handling Centre, near Romsey. The first remote control system to be employed provided the capability for differential thrust and rudder operations, proving its effectiveness in the limited space of the towing tank.

The Bluetooth connection had a limited range, but this was something to take care of rather than to change. Rudders and fairings were tested in open water, with positive results, and the improved electrical system testing came alongside trialling of all other aspects, as was required for complete operation.

Research into the concept of autonomous shipping was undertaken, and this encompassed a number of considerations beyond pure naval architecture. This would take account of a great number of aspects relating to autonomous shipping as a whole, rather than to a singular vessel; emphasis was placed on human factors and how these would apply to unmanned ships. The considerations involved legal, social, environmental, economic, and technical challenges.

Due to the differences in the design of a full-scale autonomous container vessel and *Fortitude*, there are obvious restraints as to what can be tested. However, it is possible to test autonomous concepts for the navigation, systems management and communication, and use the results from *Fortitude* testing to gain an understanding of the technical difficulties that can be expected of an autonomous containership.

The autonomous navigation system is a perfect example of this as the navigation is ultimately controlled by the autopilot, both on *Fortitude* and on containerships. This means that the brain is constant for a vessel of any size. The same code is used for decision-making, but the difference lies in how the information is inputted to make these decisions.

Imaging and radar are practical for full-scale merchant ships as the necessary equipment can be conveniently located high above the waterline. The difference in scale is that *Fortitude* does not have this luxury. However, one of the systems that can be implemented to both *Fortitude* and a full-scale vessel is an AIS (Automatic Identification System) receiver and transmitter, and this was used exactly as it would be at large scale.

The human element is comprised of the interaction of man and machines. The expectation is that by taking the human

Fortitude in brief

Team *Fortitude* was essentially eight Masters of Engineering students from the University of Southampton working on a final year project within the Fluid-Structures Interactions (FSI) Group. Their aim for the academic year was to show proof of concept for a number of autonomous solutions applicable to full-scale ships, both practically and conceptually. Six of the team come from the Ship Science course while the other two are Mechanical Engineering students – the supervisors are all from the FSI Research Group.

The team's objectives:

- **Investigate the legal, technical, economic, environmental, social and safety challenges of autonomous shipping**
- **Develop a concept design for an autonomous vessel and pinpoint which systems to be installed onboard can be investigated further, both at small scale and at full scale conceptually**
- **Implement and test these systems practically wherever possible**
- **Investigate any conceptual systems to provide a better understanding of potential autonomous operation**
- **Use the results gathered from the concept design and from practical testing to highlight any major barriers to autonomous shipping**

View from *Fortitude* at Warsash Maritime Academy's Timsbury Lake, looking towards the 'Shore Based Control Centre'

element out of the equation, the interaction of the two would need to be redefined and the risk of accidents would be minimised because of this. However, this would pose new challenges in both the design and the operation of a full-scale autonomous ship.

After the initial research, it was identified that autonomous ships will require a legal framework beyond that already in place for manned vessels. While numerous regulations are set to stand strong under the introduction of unmanned ships, the most basic definition of a vessel within the rules can be brought into question, which calls for the entire subject area to be re-assessed.

It was recognised that when quantifying the technology of the future, environmental issues must also be taken into consideration. The general trend towards reducing emissions within the maritime industry, driven by the IMO and other regulatory bodies, presses the industry to find solutions for a more efficient industry.

Research and discussion with industry showed that there is resistance to evolving employment structures within seafaring. This is despite the fact that such evolution could have long-term benefits for maritime professionals, such as the relocation of seafarers into shore-based roles, which will bring a positive change in lifestyle.

These considerations drive the technical aspects required in the design of autonomous marine systems and start from the automation of ship systems such as communications and navigation, which are ultimately required to perform autonomous decision-making and maintenance.

The prime motive for autonomy is to reduce the operating costs incurred in the day-to-day running of a vessel. Crew wages account for a significant percentage of the operating cost of a ship, and thus the minimisation of this factor can lead to a potential financial benefit for the ship owner or operator. Therefore, investigating the feasibility of an autonomous container vessel can provide a clear indication of where this concept could stand in the present maritime market.

An initial concept design was completed to validate the investigations above and to progress existing autonomous ships research,. This followed the traditional design spiral, which was used to draw out how particular systems and design processes would change with the introduction of autonomous ships. The concept also helped to improve the accuracy of initial assumptions made in the design process, which was particularly important given the lack of existing data and base vessels. A number of key areas within the concept were pinpointed and these were tested as equivalent and scalable systems using the *Fortitude* platform. These included decision-making, navigation & collision avoidance, bi-directional communications, and the processes to ensure the longevity of an autonomous vessel.

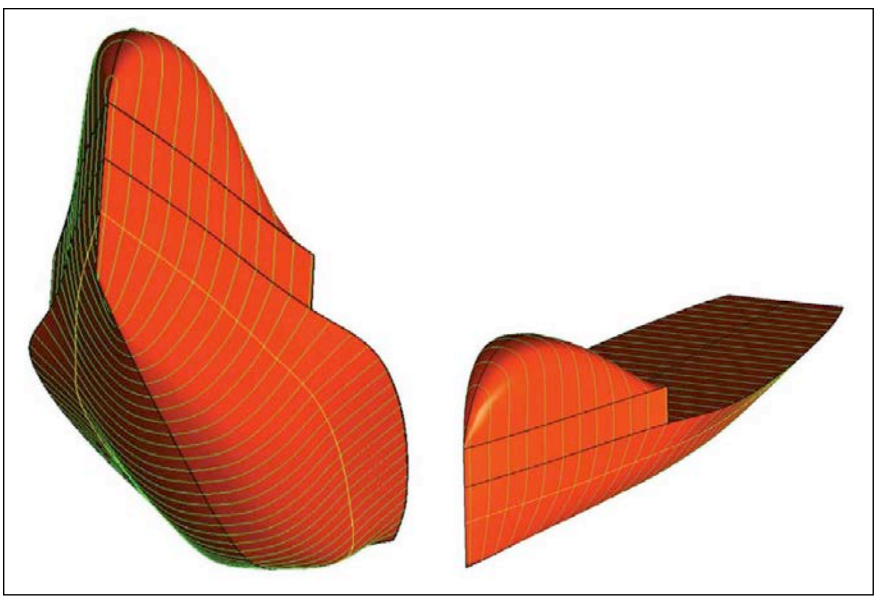
When assessing the longevity of an autonomous vessel, at both small scale and full size, the team carried out a failure analysis using Fault Tree Analysis (FTA). Quantifying the data required for this was very difficult due to the poor availability of reliable failure data, and so it was decided to use *Fortitude* to gather information from the systems installed onboard to use as comparable inputs for systems such as AIS. The results also proved that the autonomous communication system is a major barrier and there are different possibilities that could be advanced for autonomous navigation.

Decision-making will occur as a reaction to stimuli, which come from both internal and external sources and will be applicable to the entire function of the vessel – internal sources relate to the management of the power and energy storage systems. While vastly simplified, this set up is a direct validation of the process that would be operated on a full-scale ship. External sources were clearly relevant to navigation and this was exemplified through collision avoidance using both distance sensing and target object identification.

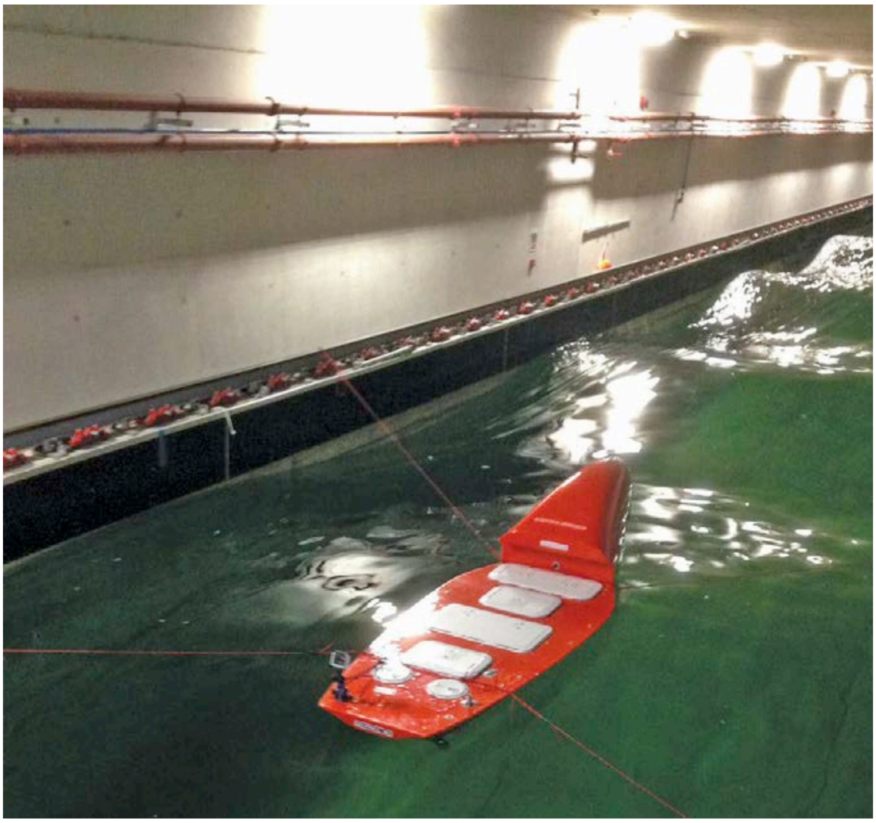
The team used a number of initial assumptions to put together the concept design brief, which then specified an operational profile for the vessel. The overall thought process for the concept design was to be the same as that for a manned vessel, but it was soon understood, from going through the process, that factors such as the electrical loads and general arrangement would have to be vastly different.

The inputs for these aspects were taken from the initial research and from these the design was improved. The reduction in the accommodation block, and the addition of LNG/diesel dual-fuel engines, as well as the reduced hotel loads placed on the vessel, highlighted key areas of potential improvement in autonomous shipping. However, the initial speculative assumptions amplified the need to refine the concept and this would offer comment for future design cycles.

It was proven, to the extent applicable to the context of this study, that an autonomous container vessel is an economically feasible solution. The initial motivation of reducing the operational cost was validated, as was the use of LNG as a propulsive fuel with the voyage cost minimised. However, as



***Fortitude*'s hull as modelled in Rhino**


Testing out *Fortitude*'s seakeeping abilities in the University of Southampton's Boldrewood Towing Tank

expected, the build cost of the ACCV was calculated to be higher than the equivalent capacity manned ship. By making a series of carefully chosen assumptions, the team avoided any hindrances to the potential conclusions drawn. The economic study for the conceptual vessel, which met the defined mission requirements and operational profile, was shown to be profitable within its own ideal context. To validate this concept further, investigations into the volatility of the maritime market and its effects would need to be completed.

The final conclusions drawn by Team *Fortitude* were that autonomous shipping could be feasible in the future. Results from the technical investigations show that there are still many barriers that need to be overcome, but these barriers can be surmounted within the near future if the maritime industry continues with a steady migration from manned shipping. This migration is motivated by the potential for economic, social and environmental benefits. It is difficult to estimate the time it will take for autonomous ships to become operational, but it is suggested that further implementation and testing, on a smaller scale such as with *Fortitude*, will push the technology closer to realisation.

With the project having been completed, it is now down to the University to push the furthering of this work, be that with another Masters group design project, a PhD project, or through other means. It is also, more importantly, down to the rest of the industry to continue towards autonomy. Team *Fortitude* have very briefly demonstrated the potential that autonomous vessels have, and it is now down to regulators to put provisions in place to allow these kinds of ships; ship owners to take the initial investment; seafarers to understand and accept the changes autonomy will bring; and the industry as a whole to push towards absolute reliability. It is no longer a question of if, but rather when this will take hold. *NA*

To stay up to date with Team *Fortitude*, head to www.facebook.com/fortitudeASV and/or www.twitter.com/fortitudeASV or to get in touch email: fdt@soton.ac.uk.

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Sponsors – EP Barrus, H-Scientific, ASV Global, BAE Systems, Barden UK, Extreme Marine and Warsash Maritime Academy

Air power; more than just a wind up

Using wind energy to power the world's fleet of ships is turning into more than just the fleeting idea of a Hollywood director looking for their latest blockbuster. Latter day idealists are turning the dream into a reality as necessity, once again, proves to be the mother (and father) of invention. Diane Gilpin investigates

Just a few short months ago in Paris the world united behind the clear goal to ensure that global increase in temperatures does not exceed 2°C. The Paris Treaty even made reference to an ambitious aim of keeping temperature rises to below 1.5°C.

In order to achieve this big goal every country in the world committed to emission reduction targets known as INDCs (Intended Nationally Determined Contributions). Shipping, empowered by the UN to effectively act like a nation state, was not included in the agreement, and did not submit an INDC. This is a problem. Not just for shipping, but also for the planet's climate.

We'll always have Paris". The deal at the COP21 meeting in France omitted shipping from the final agreement

An increase in temperature of 2°C doesn't sound so bad, certainly as I write I could use a bit more warmth. Unfortunately, the meteorological system isn't quite so straightforward. The impact of just 2°C of warming will create massive ecological system change. Sea level rises will make many of our major centres of population uninhabitable, leading to mass migration. Food crops will be more likely to fail increasing scarcity and cost of food; storms, flooding, prolonged heat waves and forest fires will increase in frequency and intensity.

This is not a challenge we can afford to kick down the road. We are already within a hair's breadth of exceeding the more ambitious 1.5°C Paris goal. February 2016 "smashed a century of global temperature records by a stunning margin", according to data released by NASA which warned of a "climate emergency". The NASA data shows average global surface temperature in February was 1.35°C warmer than the average temperature for the month between 1951 and 1980, a far bigger margin than ever seen before. The previous record, set just one month earlier in January, was 1.15°C above the long-term average for that month.

The global challenge to move to a zero emissions industry needs a change in mindset. Yacht racing and Formula 1 could show shipping the way

We must create a new global system fast enough to mitigate the impact of climate change risks which the US military describe as the 'threat multiplier'. To contextualise the danger, it is worth reading historian Timothy Snyder's chilling analysis of similarities in our current economic and political situation to the conditions that led to the rise of Naziism. Snyder's conclusion is that to avoid a repeat of history we must invest in science and technology.

Shipping as part of the solution

Under current policy, shipping's CO_2 emissions are expected to rise by 50-250% by 2050. Paris gives us a target of reaching net-zero carbon emissions by then. That gives little more than a ship's economic


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working lifetime, around 30 years, to turn things around. There is simply no room for the sector's currently expected 1.2-2.8 gigatonnes of carbon emissions in the fast approaching zero emission world.

The International Chamber of Shipping, Armateurs de France and the Norwegian Shipowners' Association - which amongst their collective membership represent most of the world's ship owners - invited industry representatives, regulators and thought leaders to discuss shipping and climate change mitigation in Paris during COP 21. As a panellist I can report that the conversation was intense with the industry seeking a clear emissions reduction target goal from the IMO. Edmund Hughes, IMO's head of air pollution and energy efficiency, put forward the view that ships were "mobile power stations" and as such could not change in the next 20-30 years; he added that it simply would not be possible to use alternative energies.

Look to the land

We only have to look to land based industries to see that the once unthinkable is becoming unstoppable. The extraordinary growth in renewable energy is dramatically impacting both the fossil fuel and investment communities.

The coal industry is collapsing. Scottish Power's Longannet station closed over the Easter weekend leaving Scotland with no coal powered stations. In the US, Patriot Coal Corp., Walter Energy Inc. and Alpha Natural Resources Inc. have all filed for bankruptcy in the past year. Now that Arch Coal Inc., the second largest coal miner in the U.S., has joined their ranks, along with the Peabody Energy Corp., which reportedly filed for Chapter II bankruptcy protection in the US on 13 April. Most major international corporations like Unilever, Tata, and Virgin have, very publicly, committed to becoming net zero emission by 2050. They will not fail.

As shipping is the servant of global trade it must urgently provide the ultra-low carbon logistics service that the cargo owners need to enable them to reach their own national and/or commercial emissions commitments. Public pressure on high profile organisations, like Walmart, to measure and reduce their shipping emissions is driving increased pressure on the industry from cargo owners.

A record US$286 billion was globally invested in renewables last year

Global challenge

I'm fortunate enough to have worked in both F1 and offshore yacht racing. It's that mind-set that is beginning to be unleashed in the shipping sector. The challenge the international community has set commercial shipping, is that within the lifetime of a ship, vessels will have to operate in a net zero emission economy. How can shipping achieve that? It starts with innovative thinking and 21st century technology; naval architects are the people to design the new golden-green age of shipping. In embracing the new post-Paris reality, far from being a threat, de-carbonisation is slowly being embraced as an opportunity. Of particular interest is the potential of renewable energies – wind and solar – power sources that are abundant, free and exclusively available to ships. Envisioning a rapid transition to maritime renewables was considered crazy just five years ago but certainly the winds of change are being felt. Small but highly significant investments in maritime renewables are being put in place.

Savvy investors across the world have internalised the logic of the Paris Agreement's goals and recognise that the days of carbon intensive business models are over.

More than twice as much investment went into capacity to generate electricity with renewables than into fossil fuelled power stations, according to a study by the Frankfurt School of Finance and Management for the UN Environment Programme. Over the past decade, technology development has cut the cost of solar panels and wind turbines by up to 80%. Renewable energy is often now no more expensive than that derived from fossil fuels and, critically important from a business planning and management perspective, offers much greater long term cost certainty – once the capital cost is funded fuel is free, whereas fossil fuelled assets are dependent throughout their lifetime on volatile commodity fuel prices, which come with the very real potential that a carbon tax will be levied on them, which then brings the added risk of becoming stranded assets.

Investors eager for new opportunities in this burgeoning clean energy space are warming to the idea that there's great potential in maritime renewables. After all, today's global economy was built on wind-powered ships and we can expect a 21st century renewable powered vessel to be as different from the Cutty Sark as an offshore wind turbine is to an 18th century Dutch windmill. Same power source, new technology.

Committing to the Paris Treaty

For the technology transition to be fast and deep shipping's leadership must join the rest of the world in setting ambitious goals for decarbonisation. The UN empowered the IMO to act on behalf of shipping in international climate negotiations. Between 18 and 22 April the IMO's Marine Environment Protection Committee (MEPC) had its first post-Paris opportunity to discuss greenhouse gas (GHG) emissions at MEPC 69. The political process for adopting any target is laborious, but there is a distinct change in the air.

The International Chamber of Shipping, representing over 80% of the world's merchant fleet, has called upon the IMO to develop an INDC to clarify CO_2 reduction targets for the international shipping sector as a whole, signifying a fundamental shift in the organisation's stance on GHG emission reductions. The ICS submission was received with great media interest and has been welcomed by environmental organisations.

The Marshall Islands together with the Solomon Islands, Belgium, France, Germany and Morocco have co-sponsored a paper to MEPC 69 calling for the development of a work plan to define shipping's fair share in reducing its

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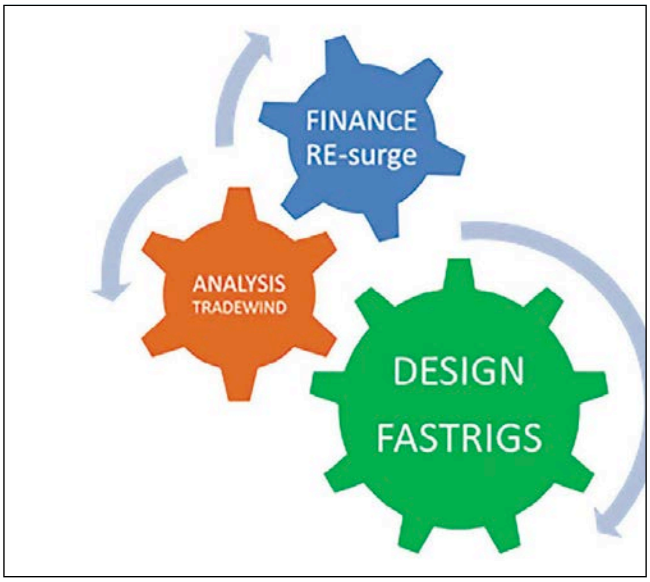


Learning from the onshore wind industry shows that shipping must stimulate design, finance and performance analysis

GHG emissions. Canada, the Netherlands and Vanuatu have pledged to support the motion from the floor and work is ongoing to rally further support.

The Clean Shipping Coalition is supportive of the proposed 'fair share' discussions and underlines the need for ship GHG emission reductions to contribute towards keeping global warming "well below" 2°C.

The World Shipping Council, Cruise Lines Industry Association, INTERTANKO, and International Parcel Tanker Association are also publicly supportive of the proposed 'fair share' discussion.

Elsewhere major ship owners along with industry associations have publicly voiced their disappointment about shipping not being included in the Paris Agreement, including Maersk, Wallenius Wilhemsen, the Danish Shipowners Association, and the European Community Shipowners' Associations. As a reaction, the latter three are reported to be planning the formation of a new global industry alliance aimed at exerting an increased level of pressure on IMO towards introducing further GHG reduction measures. The Danish Shipowners' Association plans to set out its own CO_2 reduction goals; Swedish Shipowners are committed to become zero emission.

The IMO's stance on the topic also seems to be changing. At the beginning of February, IMO Secretary-General Kitack Lim, who took over the post from Japan's Koji Sekimizu on 1 January, stated that "contributing to the fight against climate change is a top priority for IMO". While the decision rests with member states, he believes "that IMO will be able to agree on the appropriate way forward", adding that "IMO looks to play a leading role in the drive towards a sustainable maritime sector." This should be viewed against the statements of the outgoing Sekimizu in September 2015, warning that an emissions cap would "artificially limit" the sector's growth.

There are also an increasing number of voluntary industry schemes aimed at reducing GHG emissions from ships. The most notable example is the green ship initiative launched in January 2015 by the Liberian Registry, the world's second largest ship registry. The initiative is designed to reduce global carbon emissions, enhance fleet efficiency and competitiveness, and promote a greener Liberian fleet, and offers special tonnage tax discounts for participating ship owners.

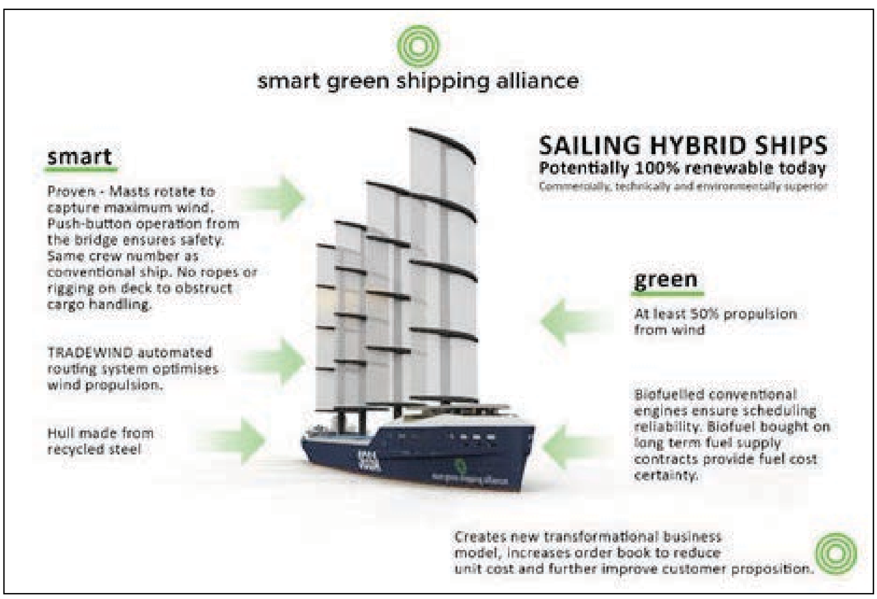
The conducive environment

The necessary conditions for rapid technology change are coming into alignment. Shipping's customers are creating the strong commercial demand pull for low carbon ships. Simultaneously, policy is looking increasingly likely to implement a 'push' through of targets and / or regulation.

To rapidly accelerate the necessary design and development there is much we can learn from the evolution of the onshore wind industry. Three different but dynamically interconnected disciplines need to be stimulated to accelerate the uptake of maritime renewables technology – design, finance and reliable performance analysis.

The first wind turbines were capable of producing 50kW power, now, within just a few years, offshore turbines with 8MW generating capacity are being installed far out to sea.

Smart green ships are a commercially viable proposition



The Smart Green Shipping Alliance (SGSA) has the same ambitious trajectory of development for commercial shipping.

Minimising carbon starts on naval architects' drawing boards. Designing for 100% reuse reduces carbon by 29% according to research led by Dr Paul Gilbert from the University of Manchester and Dr Peter Hodgson from Tata's sustainability team. Build the vessel for extreme longevity, looking to condition based monitoring, new materials and operational approaches to extend use of asset, which further reduces embedded carbon over time. Power the vessel with 100% renewable energy allowing fuel costs to be predictable over the lifetime of the ship and we can envisage today an ultra-low carbon, future-proof resilient asset through combining existing and proven technologies in new ways.

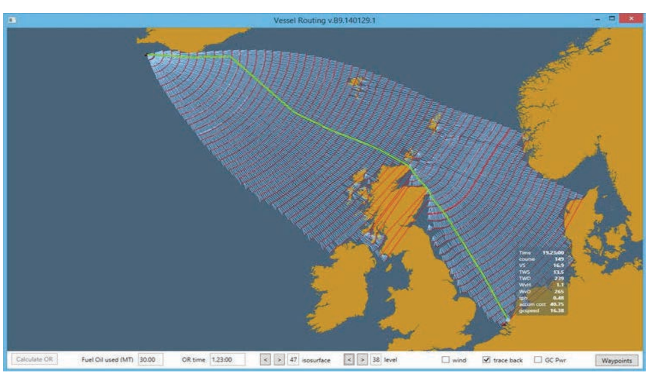
Once the collective creativity of the shipping industry realises the potential in maritime renewable energy we can anticipate an exponential growth mirroring that of onshore renewable energy.

New financial products triggered the onshore renewable revolution and the SGSA is creating innovative business models for the maritime sector that reflect the fundamentally different economics enabled by renewable energy – the asset is decoupled from volatile commodity fossil fuels and harnesses, through technology, freely and infinitely available power.

The final piece in the jigsaw is the replication for the maritime sector of the analysis tool that underpinned the development of onshore wind. 'Virtual Met Mast' created by the Met Office enabled all contracting parties – asset developer, financier, end-user – to be able to confidently predict the value of the wind to any project, to effectively monetise the value of renewable energy and give all contractual parties confidence.

Of course maritime analysis is inherently more complex. The windy hill where we might develop a fleet of wind turbines is static, unlike hybrid-wind powered ships which move through waves and currents as well as variable meteorological conditions. But by mobilising the power of Big Data the SGSA is, with the Met Office, developing a tool called Tradewind to perform a similar function to Virtual Met Mast. It can analyse new vessel designs against 30 years hindcast data in wind, wave and currents, enabling a reliable valuation of the contribution from the wind on any ship on any route. Monetising the value of the wind and making the unpredictable predictable enables rapid design optimisation. *NA*

Vessel routing using tools such as the Tradewind meterological service will aid ship efficiency



Royston's enginei infomatic

Shervin Younessi, technical manager of Royston enginei, looks at how the statistical analysis of Big Data for the automatic detection of vessel operational modes can provide more reliable and meaningful engine performance monitoring

Vessel operational performance, fuel optimisation, the reduction of emissions, and efficient engine maintenance decisions have become crucial in enabling ship operators to meet various technical and maritime regulatory responsibilities.

To help meet this challenge, accurate fuel monitoring systems have grown in popularity on all types of vessels, drawing on the use of sophisticated communications and navigation systems and interfacing with ever more advanced engine sensor technology.

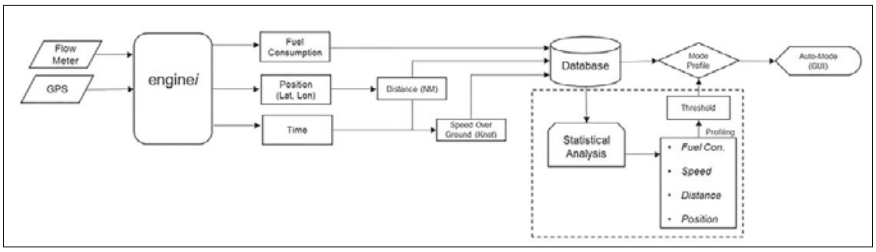
Now, bringing all these advances together, the intelligent collection, processing and analysis of this wealth of data provides even greater potential to identify faults and improve vessel efficiency, as well as contributing to operational decisions for optimal performance, regulatory compliance and condition-based maintenance.

Growing ship owner focus on vessel performance issues, with accurate bunkering and fuel management reporting, has prompted an upsurge in interest in marine engine monitoring systems.

The most advanced marine fuel monitoring systems now allow fuel consumption, vessel speed and distance data, and other variables to be considered against different operational modes defined by the specific activities of the vessel.

Although some standard modes, such as stand by or transit, are common in all vessels, others are specific to different types of vessel and can include, for example, towing operations by tugs or dynamic positioning manoeuvres for offshore supply vessels.

However, existing engine monitoring systems rely on the manual entry of the operational mode into the onboard system. Consequently, the detailed and accurate comparison of fuel or engine performance data can be compromised by human error.



Overview of the automatic mode detection

For example, different members of the crew may recognise or register different operational modes based on their experience (or inexperience) or there may be time delays in logging changes to the type of activity being undertaken.

As a result, the potential for human error increases the risk of unreliable data being generated, meaning that the accurate correlation of engine and vessel performance information needed for making important operational decisions can be compromised.

Maritime Big Data

New sensor technologies are being implemented rapidly in the marine engineering sector, allowing real time monitoring and control of a wide range of factors associated with vessel operation. In addition, associated with the introduction of new sensor capabilities, the industry is moving ever nearer to autonomous operational systems.

Different sensors used onboard vessels collect wide ranging information, including GPS (speed, position, time), anemometer readings (wind conditions), engine fuel flow, engine shaft torque, shaft RPM and other variables.

As a consequence of this, Big Data has become a buzzword in the shipping industry. However, with data transmission rates increasing, and with different sensors feeding greater intelligence into the system, more information is being collected in ever shorter timescales.

For this data to provide meaningful information for conversion into important operational decisions, it must be synchronised, validated, and the relevant features extracted, in an accurate and meaningful form.

This brings its own challenges in terms of sorting, analysing and interpreting data, but the value associated with this process has the potential to improve onboard operational and maintenance decisions – and offshore fleet management considerations.

In this way, the increasing interdependencies of sensor data has the potential to allow fuel and engine monitoring systems to become more valuable and data rich, helping to optimise their role in decision making.

To evaluate the potential for 'data rich' fuel management systems, diesel engineering specialist Royston Ltd. embarked on a special project that combines advances in sensor technologies with Big Data statistical analysis to enable vessel operational modes to be detected automatically.

Royston's enginei fuel management system acquires comprehensive real time engine and vessel performance measurements beyond the usual RPM, GPS and fuel inputs to take in a wide range of other engine control unit outputs.

All data collected by the enginei system can be automatically incorporated into daily reports and vessel energy efficiency plans in a range of formats. On the bridge and in the engine control room, touchscreen monitors show all aspects of key vessel performance criteria using displays and presentations of trending graphs against voyage data. The information captured onboard is made available for remote interrogation by onshore management and supervisory staff through a secure online portal and web dashboard.

In the conventional enginei programme, the system is informed of the specific operational mode of the vessel during which performance is being monitored by a crew member simply using push button activation.

To extend the capabilities of the enginei system and provide a more reliable alternative to manual mode intervention, Royston has worked with specialists from Newcastle University's School of Marine Science and Technology on the detailed statistical analysis of ship data.

In practical terms, fuel consumption rates from fuel line flowmeters and positional data from GPS sensors are collected by the enginei system for each minute of a voyage. The GPS data enables speed, distance and position information to be calculated, and this is used for analysis alongside fuel consumption for mode profiling and the calculation of the variable thresholds against which individual operational modes can be determined.

In this way the enginei monitoring system generates four input variables for statistical analysis to identify the different modes utilised in different operational conditions. This data is managed in a two stage process to establish the predicted operational mode on a minute-by-minute basis.

Historical data needs to be statistically analysed to determine the operational behaviour of the vessel. This is carried out in Step 1 and the results enable the mode profile to be created in Step 2. Step 1 is conducted only once in the auto mode determination process, and after the established mode profile is created, all data goes directly through that profile from Step 2.

Statistical process control (SPC) and data correlation analysis techniques are used to identify the profile limits for the different operational activities (modes) undertaken by the vessel.

SPC techniques involve defining the distribution of the process and continuously monitoring and comparing process performance. Correlation analysis considers the strength of linear relationships between multiple input variables.

As part of this approach, in the Royston enginei auto-mode project, individual (I) and moving range (MR) charts displayed process performance and detected changes in time ordered data to examine individual limits.

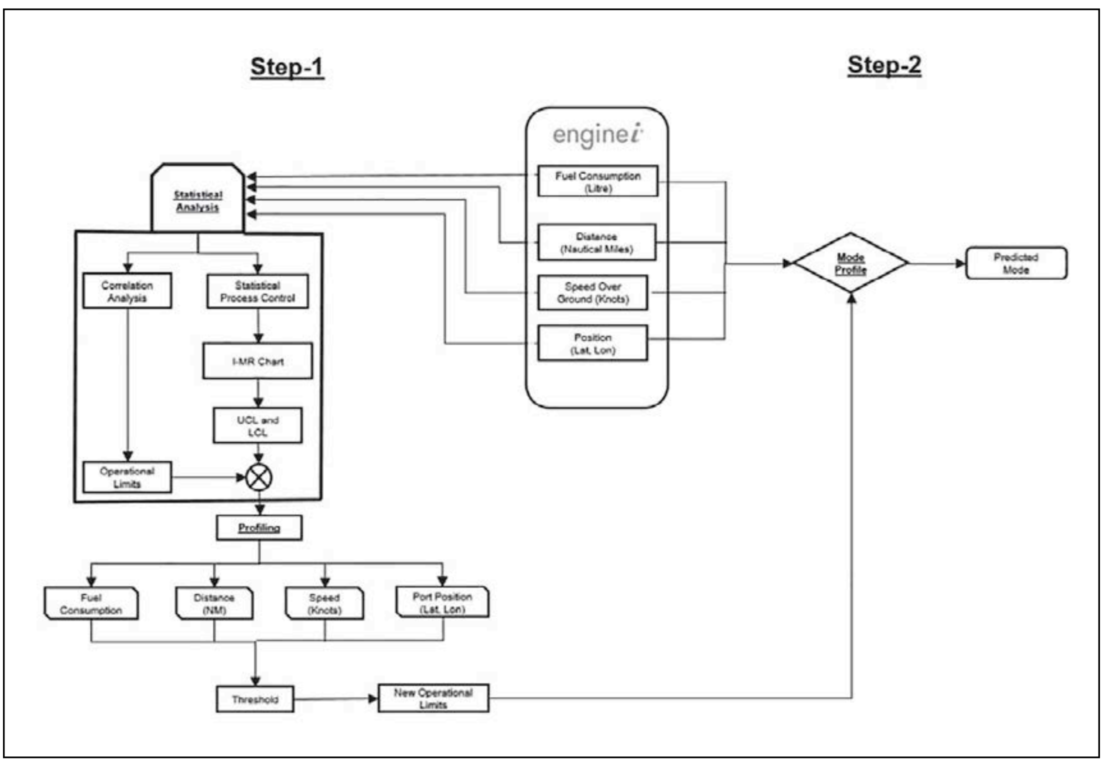
The I-MR chart is used to detect changes in time ordered data to examine individual values and the control limits are calculated using the average moving range. Separate charts are created for fuel consumption per minute, distance travelled, and speed, to enable performance to be compared, and upper and lower control limits to be derived for each different mode.

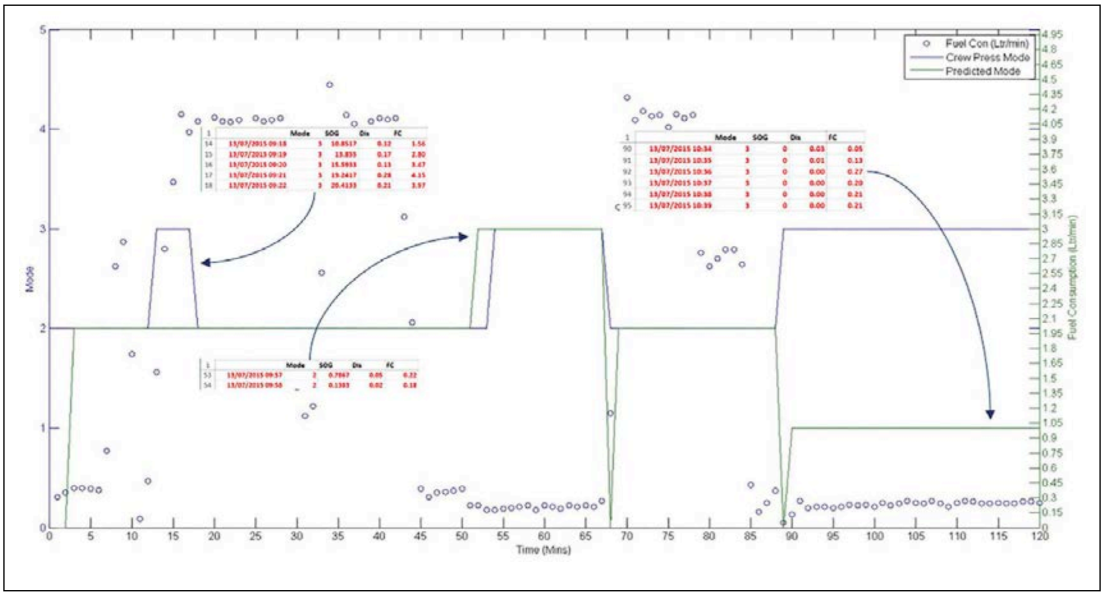
Minute-by-minute analysis of the data provided by the sensor inputs enables the operational mode limits in different conditions to be determined for each vessel.

In practice, this means that after installation of the enginei system on a vessel, the initial data generated by the sensors is used to create individual mode profiles – and it is against these 'templates' that actual operational data is assessed during auto mode detection.

As the enginei system records data for analysis and automatic interpretation, the operational mode is identified on a rolling minute by minute basis. This means the vessel mode can be accurately identified and the associated performance information can be displayed on the bridge monitors, as well as the on-shore

The auto-mode detection system





Implementation of auto-mode detection onboard *Princess Royal*

maintenance and supervisory staff through a web portal.

Case study comparisons

As part of this project the enginei was installed on two trial vessels, the University's research vessel *Princess Royal* and a specialist offshore support vessel (OSV).

Princess Royal is powered by two Cummins QSM11 (600hp) engines with fixed pitch propellers, has a cruising speed of 15knots and a maximum speed of around 20knots. The OSV has a diesel electric propulsion system with four main Caterpillar engines (1901kW) and two auxiliary engines. The vessel speed is approx. 16.5knots.

The Royston enginei system was used to monitor the operational behaviour of both vessels, enabling typical operational mode profiles to be developed for each of them based on the statistical analysis of fuel consumption, distance travelled, and speed data provided by the sensors.

The enginei auto-mode detection system was assessed on the *Princess Royal* and OSV trial vessels, comparing the initial crew indicated operational modes by 'manual' activation with automatic predicted modes encountered on a typical journey.

Based on the profiling of *Princess Royal*, three operational modes were identified, comprising Mode 1 – Port, Mode 2 – Transit and Mode 3 – Stand By. Four modes were identified in the OSV, with Mode 4 – Dynamic Positioning – being added to the original three types of operation.

An additional mode was also incorporated (Mode 0) as 'undefined' to cover those occasions when a vessel's operational activities are affected by external factors, such as sea conditions, tidal movements, or wind strength; when actual data does not correspond to any of the established operational profiles.

The figure above for *Princess Royal* over a two hour journey shows a comparison between the manual indications of operational mode and the automatic predicted status based on sensor data. There appears to be three occasions when the manual and predicted operational modes are different.

For example, in the chart above, from 12 to 18 minutes into the journey, the crew indicated the vessel was in standby mode, yet during this period the vessel speed over the ground was 10 – 20knots, this was clearly in transit mode. This was properly identified by the auto-mode detection system. Similarly, after 91 minutes, the crew indicated standby mode, but GPS tracking reveals that the vessel was in port.

In total, the undefined mode was allocated to only eight of the 120 data samples gathered in the two hour journey. The auto-mode system corresponded to the manual indication of operational mode in 62% of analyses. As a result, the auto-mode system correctly identified 38% of the operational modes that were incorrectly entered by the crew.

With the OSV, 1,440 data samples were analysed during the course of a full day's operation by the vessel. On only three occasions was the operational mode 'unidentified' because of external factors. Overall, 88% of the operational modes were consistent across manual and automatic identification and the auto-mode system corrected 12% of the manual entries.

By converting fuel consumption into fuel mass by considering fuel oil density, and using an agreed fuel emissions factor, it is also possible to calculate the CO_2 emissions associated with different operational modes.

For the OSV vessel in the Royston trial, the table (on page 69) shows a summary of engine performance during different activities and the resultant CO_2 emissions.

Summary reports of this nature help to provide an overall indication of the vessel performance so that the crew and onshore monitoring staff can best identify the most economic operational modes and develop their own KPIs for different voyages or contracts.

Using the more reliable information provided by auto-mode detection enables individual engines to be monitored and maintenance requirements to be determined.

The research undertaken by Royston and Newcastle University demonstrates the ability of the enginei auto-mode system to correctly identify the different operational modes and the fuel consumption rates associated with different vessel engines and different activities.

A vessel's fuel consumption and operational profitability depends largely on engine condition and performance. The accurate monitoring of a set of parameters linked to the condition of the marine propulsion system therefore allows shipping operators to identify any significant changes in engine performance that could be an indication of developing faults or required maintenance.

By identifying individual operational modes automatically, the auto-mode capability removes the risk of human error introduced by the manual intervention of crew members and avoids the consequent danger of the wrongful interpretation of data.

In this way, the thorough processing and statistical analysis of sensor data enables more reliable vessel and engine performance data to be produced. This means that onboard engineers and offshore fleet management staff have the ability to make more informed and accurate decisions based on trusted information.

With condition based monitoring and maintenance systems increasing in importance, and emissions control becoming a critical regulatory requirement, the improved monitoring of operational performance provided by auto-mode detection represents a significant technological advance in the marine engineering sector. *NA*

		Vessel Mode Coa. (Litres)					
		Mode-1 Port	Mode-2 Transit	Mode-3 Stand By	Mode-4 DP	Individual Engine Con (Litres)	Individual Engine CO_2 Emission (Tonnes)
Engine Fuel Con (Litres)	Eng-1	59.81	2443.5	80.69	8.84	2592.84	7.08
	Eng-2	43.57	1078.4	59.6	7.32	1188.89	3.24
	Eng-3	67.62	2165.3	53.69	6.8	2293.41	6.25
	Eng-4	0	0	0	0	0	0
	Aux-1	549.64	2.5	0.86	0	553	1.51
	Individual Engine Con (Litres)	720.64	5689.7	194.84	22.96	6628.14 (Total)	--
	Individual Engine CO_2 Emission (Tonnes)	1.96	15.52	0.54	0.06	--	18.08 (Total)

Performance monitoring based on summary from the auto-mode detection of the OSV for one day

Addendum

The Royston enginei integrated fuel management system is compatible with all marine engine types and can be interfaced with new-build engine installations or retrofitted to operating vessels. Full details at www.enginei.co.uk.

Rederi AB Gotland looks to the future

Nutrient removal in membrane bioreactor wastewater treatment systems is the future, says Rederi AB Gotland, who add they are now acting for both savings and the sake of our seas

Sweden's oldest passenger shipping company Rederi AB Gotland, has chosen Evac products to equip its new LNG-fuelled passenger and cargo vessels which will ply Baltic Sea routes. Each vessel will carry approximately 1,700 passengers and crew, and since the Baltic Sea is classified as a Special Area (SA), the new vessels will also carry a state of the art nutrient removal system.

The new LNG-fuelled vessels will operate in the Baltic Sea, classified as a Special Area, and will feature nutrient removal systems

Nutrient removal; not just a mechanical device

Each of the new vessels is equipped with two membrane bioreactors (MBRs), solids screening, 233 vacuum toilets, two buffering tanks, two macerating food waste feeding stations, and one bone shredder.

Each MBR unit is also equipped with a nutrient removal system. Evac product manager, Mats Riska, says that in the past wastewater treatment was viewed as "one more piece of mechanical equipment onboard." But due to compliance requirements for wastewater treatment, all that has changed.

In SAs like the Baltic Sea, ships will soon be required to remove nutrients like nitrogen and phosphorous before returning water to the sea.

"Nutrient removal is a complicated biological and chemical process," says Riska. "Thanks to Evac's systems this process can be fully automated so that only a basic process understanding is required from our customers."

Since only some vessels are destined for SA waters, and because only some ship owners demand it, nutrient removal is not standard on Evac MBR systems. However, because compliance regulations will require it in the future, all Evac MBR systems are built to allow an easy upgrade to nutrient removal.

"Our standard MBR is easy to retrofit to meet compliance requirements, with nutrient removal supplied as a one skid installation," says Riska. "Our product array is very much poised for the future."

Factoring in future compliance costs, an Evac MBR with upgrade capability makes Evac MBR systems the most competitively priced on the market. "It's much more cost effective to upgrade than to do a full retrofit," says Riska.

Touch screen

Another feature found on the Rederi AB Gotland vessels' MBR units is a touchscreen control panel.

"We gave a total facelift to our MBRs at the beginning of 2015," says Riska. "We went from mechanical switches to a touchscreen with a great user interface. Rederi AB Gotland will be using the first ones we've shipped."

The touchscreen system offers data logging for all parameters. The user can check process values, and make log data available to Evac for easy service.

Made in China

Rederi AB Gotland is also breaking tradition with the two vessels being built in China. Guangzhou Shipyard International (GSI), the largest, most modern shipbuilding company in Southern China, was awarded the job.

GSI is China's leader in handysize oil/chemical tankers (up to 50,000dwt), but it is also a company known for undertaking the manufacture of special vessels like the pair for Rederi AB Gotland.

Huang Sheng Ming, the piping engineer responsible for the design management work on the two vessels, is charged with signing technical agreements with systems makers like Evac. Nutrient removal is an area of growing concern to Huang.

"Nutrient removal is a requirement for the near future," says Huang. "MBR and nutrient removal is our first contact, and with this trend we're still in the learning stage. But by working with Evac, we are slowly getting to know the rules and the importance of MBR."

Evac is a provider of integrated waste-, wastewater-, and water management systems for the marine, offshore, and building industries. The company has executed over 20,000 marine and 2,000 building projects worldwide. *NA*

Cleaner cruising gathers momentum

New technology and the use of LNG as fuel for cruiseships are two topics that have featured highly in recent months for the cruise industry with the release of new products and the forthcoming introduction of new environmental legislation. *Sandra Speares reports*

LNG as fuel was a prominent topic at the Seatrade Cruise Global conference and trade fair in Fort Lauderdale in March, with some commentators estimating that as much as 80% of the cruise fleet will be running on LNG by 2025.

While logistical issues relating to the use of LNG for passenger ships continue to be raised, new environmental legislation, including a 0.5% global sulphur cap in 2020 or 2025, make LNG an attractive option.

One concern is logistics, both from the point of view of availability of LNG in sufficient quantities to meet demand and also as regards adequate shore-side facilities to cater for it.

If cruiseships have been installing scrubbers as a means to overcome the low sulphur issue, they have also been investing in LNG as demonstrated when Carnival signed a contract last year for four LNG powered cruiseships with German shipbuilder Meyer Werft.

Another cruise company to move into the LNG as power sector is MSC Cruises, who recently announced a massive investment in shipbuilding at STX France's facility at St Nazaire.

The privately owned MSC Cruises signed a letter of intent with STX France for the construction of up to four LNG-powered vessels of over 200,000gt in April. The four ships, the first one of which would be delivered in 2022, will be based on yet another advanced next-generation prototype and will form what will be known as the 'World Class'.

A spokesperson for MSC said that they are not releasing further technical details of the new ship design for the moment. Commenting at the signing of the letter of intent, which took place in the presence of French president Francois Hollande, MSC Cruises executive chairman, Pierfrancesco Vago, said the announcement was "a reflection of our constant commitment to innovation, as we will partner with STX France to design yet again a completely new prototype – already the sixth in our history. In fact, in yet another industry-first, the new MSC Cruise World Class prototype will feature - amongst other highly innovative elements - a record-breaking, futuristically-conceived design that will make the ship a truly unique place to be at sea, whilst maximising the open air space available to guests."

AIDAprima is the first cruiseship to be fitted with Mitsubishi Heavy Industry's Mitsubishi Air Lubrication System

The new orders, worth about €4 billion (US$4.52 billion), bring MSC's investment in new cruiseships during a 10-year investment period to approximately €9 billion (US$10.18 billion). MSC Cruises' investment plan includes orders with STX France for two Meraviglia and two further Meraviglia-Plus Class ships, as well as orders with Fincantieri for up to three next-generation Seaside Class ships. Additionally, the plan encompassed the €200 million (US$226.35 million) so-called Renaissance programme for four ships in the fleet, which was also carried out by Fincantieri.

MSC Cruises announced in January a partnership with Samsung to fully equip all of its next-generation ships, starting with *MSC Meraviglia* and *MSC Seaside* which come into service next year, with digital equipment including visual displays, mobile technology and medical equipment.

In considering the use of LNG for the cruise industry, some concerns centre on suitable training for crew members on cruiseships powered by LNG and also general safety issues for passenger ships when bunkering LNG while passengers embark or disembark.

Given the need to accommodate LNG tanks on vessels, most observers suggest that LNG as fuel is most appropriate for newbuilds. With most cruise lines involved in extensive newbuilding programmes, LNG is increasingly an option for the future.

Further questions surround connectivity, an issue that has raised its head for many years with cold ironing in ports as the environmental legislation began to bite.

Do cruiseships have fittings that are compatible with shore-side facilities as far as fuelling is concerned? According to Fred Danska, director of cruise business at Wärtsilä, who spoke at the Seatrade conference, it would be good to have standardised fittings for shore-side bunkering, and the supplier for the LNG ferry *Viking Grace* has made their design available for others in order to facilitate bunkering standardisation. Wärtsilä supplied the propulsion machinery for *Viking Grace*, the world's first LNG powered passenger vessel which was launched in 2013.

Engine manufacturers like Wärtsilä have taken the view that "technology development did not end with the dual fuel engine" and it markets LNGPac, a complete system for LNG fuel handling, including the bunkering station, the storage tank and all essential control and monitoring systems.

One example of a cruiseship fitted for LNG is *AIDAprima*. Mitsubishi Heavy Industries (MHI) completed delivery of the *AIDAprima*, the first of two large cruiseships being built for AIDA Cruises at MHI's Nagasaki Shipyard & Machinery Works in March.

The 125,000gt *AIDAprima* is 300m in length, it is the world's first cruiseship equipped with the Mitsubishi Air Lubrication System (MALS), MHI's proprietary technology that enhances fuel efficiency. Air blown out from the vessel's hull bottom produces small air bubbles that cover the vessel hull like an air carpet, reducing friction between the hull and seawater during navigation. MALS also enables a significant reduction in energy usage and carbon dioxide emissions.

Other cutting-edge technologies onboard that save energy, increase automation and reduce manpower needs, include a pod propulsion system, liquefied natural gas (LNG) fuel supply system, the latest gas emissions treatment system, and a new air-conditioning system that saves on energy consumption by using waste heat.

Arctic activity

Cruise companies' Arctic programmes have meant investment in a wide range of technology, not least with the opening up of the Northwest Passage.

Crystal Cruises has selected Rutter's sigma S6 Small Target Surveillance (STS) and Ice Navigator systems for the planned Arctic summer cruise in 2016 of the *Crystal Serenity* via the Northwest Passage.

The sigma S6 Small Target Surveillance system will be installed on *Crystal Serenity* and will provide enhanced small target detection of first-year and multi-year sea ice as well as other floating hazards to safe navigation.

During the voyage, *Crystal Serenity* will be accompanied by an escort vessel that will carry additional safety and environmental protection equipment. A dedicated sigma S6 Ice Navigator radar system will be installed on the escort vessel to allow for the detailed sweep of the area in advance of *Serenity*. "Rutter's sigma S6 and WaMoS enhanced marine safety, security and environmental monitoring radar systems are used globally, with extensive use for ships operating in the Arctic and Antarctic", says Fraser Edison, Rutter CEO.

Following the launch of Crystal Yacht Cruises' 62-berth *Crystal Esprit*, Crystal Cruises have announced an order for what it claims to be the world's first purpose-built polar class mega-yacht, *Crystal Endeavour*. The 25,000tonne vessel will be 182m in length, with 200 berths. It will be designed for global expeditions in the Arctic, Antarctic and tropical conditions.

Although Crystal claim the mega-yacht will be the first purpose-built Polar Code compliant yacht in the world, with a PC6 Polar Class designation, Scenic have already announced Polar Class 6 for its *Scenic Eclipse*, also due for delivery in August 2018.

Both ships will thus be able to cruise in Polar Regions during the summer and autumn in medium first year ice, which may include old ice inclusions. Both ships will also be fitted with offshore dynamic positioning technology, with computer-controlled systems that automatically maintain the ship's position using its propellers and thrusters.

With a Remotely Operated Vehicle (ROV), expedition cruises will also be organised to see sunken galleons, warships, and other ships, such as White Star Line's *Titanic*, lying at 3,800m (12,500 feet). *Crystal Endeavour* will also

Crystal Serenity will use Small Target Surveillance (STS) and Ice Navigator systems to detect hazards during its Northern Sea Route journeys

Scenic Eclipse will be among the first cruise vessels to be awarded the class PC6 Polar Class notation allowing the ship to operate in both Arctic and Antarctic waters

be equipped with Seabobs - technically advanced and powerful underwater scooters.

Steel cutting for the ship will begin May 2016 and Crystal will take delivery in August 2018. The ship is being built by Lloyd Werft.

The first piece of steel was recently cut at Meyer Werft in Papenburg for the construction of the second ship with the construction number S. 712 for Asian operator Dream Cruises, a sister company of Crystal Cruises.

Delivery of the ship is planned for autumn 2017. The sister ship will be delivered later this year. Both new ships for Dream Cruises will be about 151,000gt and have a capacity of more than 3,300 passengers.

Each ship is 325m in length, 39.7m across the beam and will reach a trial speed of about 23knots. These new ships are designed for the fast growing Chinese cruise market.

Crystal Cruises, a subsidiary of the Genting Hong Kong group, has an option to purchase the iconic *USS United States* which was signed in February. The company plans to carry out a feasibility study on whether the ship, which was built in 1952, can be restored with a view to serving once more as a luxury cruiseship. The conservation project, should it go ahead, is likely to prove a challenge for naval architects and others seeking to ensure the ship complies with up-to-date safety standards. The feasibility study is expected to be completed this year.

The Costa Group has also announced an order for two new ships to be built by Italian shipbuilder Fincantieri. The ships, each with 135,500gt and carrying 4,200 passengers, will be delivered in 2019 and 2020.

They will be operated by Costa Asia, the Asian brand of the Costa Group, and specifically designed for the Chinese market.

Costa Asia's new ships are part of contracts signed recently by Carnival Corporation with Fincantieri to build five new ships by 2020 at the company's shipyards in Monfalcone and Marghera.

Another cruise line to invest further in the expedition sector is Ponant of Marseilles, who has signed a letter of intent to order four new expedition ships, with the first to be delivered in 2018.

The additions will join the existing sailing yacht *Le Ponant* and the expedition ships *Le Boréal*, *L'Austral*, *Le Soléal* and *Le Lyrial*, with the new vessels designed to operate with 92 staterooms and a crew of 110. Ponant's new ships will be Polar Class 6 ranked.

New technology

Finnish company Valmet will supply exhaust gas scrubber systems (EGCS) for two new cruise vessels, *Mein Schiff 7 & 8*, to be built by Meyer Turku for TUI Cruises. The scrubber system deliveries to the first vessel will start in the fourth quarter of 2016 and to the second vessel in the first quarter of 2017.

The value of the order has not been disclosed. Typically, the order value of scrubber system deliveries ranges between €1 and 6 million (US$1.13 – 6.78 million).

The scrubber system delivery will include integrated hybrid scrubber systems for both engine rooms and all auxiliary systems with automation. The exhaust gas is washed with seawater in open loop mode and with recirculated water and alkali in closed loop mode. Wash water is cleaned with Valmet's patented water treatment system. All emissions are continuously monitored and the complete exhaust gas scrubber system is controlled with Valmet's proven marine automation.

Cruise companies' approach to the scrubber versus low sulphur fuel issue has tended to vary, although Carnival Corporation announced a huge programme for fitting exhaust gas cleaning technology two years ago; the aim was to equip almost three quarters of its fleet with scrubbers in order to meet its own environmental targets.

New cruise developments

Viking Sea, the second of six cruiseships Viking Ocean Cruises has ordered from Fincantieri, was delivered in March in Ancona.

With a gross tonnage of about 47,800tonnes *Viking Sea* has 465 cabins with accommodation for 930 passengers, and a total capacity of over 1,400 people, including the crew.

The ship has been designed by an interior design team of London-based SMC Design, and Los Angeles-based Rottet Studios. The Viking Ocean Cruises units are all built according to the latest navigation regulations and equipped with the most modern safety systems, including the safe return to port classification. In case of fire or flooding of some areas the ships are capable of returning to the nearest port thanks to plant design, guaranteeing redundancy and functionality of main systems needed for ship propulsion and passenger safety and comfort.

Furthermore, they feature the most advanced technologies for energy saving, including energy-efficient hybrid engines and an exhaust gas cleaning system.

The first of the series, *Viking Star*, was delivered in spring 2015 from the shipyard in Marghera, while *Viking Sky*, recently launched in Ancona, is scheduled for delivery in February 2017. *Viking Star*, was the first ship built by Fincantieri to have two closed-loop scrubbers, which remove sulphur oxides from the ship's exhaust gas by scrubbing it with sea water or fresh water.

Two new cruise vessels being built for US-based Seabourn Cruise Line by Fincantieri will feature a broad assortment of Wärtsilä propulsion, electrical and automation solutions. The *Seabourn Encore* is already under construction and *Seabourn Ovation* is scheduled to join the Seabourn fleet in 2018. The contracts with Wärtsilä for the vessels' navigation and automation systems were signed in December 2015. The engine orders were signed in late 2014 and in the third quarter of 2015.

Royal Carribbean is continuing its newbuilding programme with the arrival of the 168,666gt *Ovation of the Seas* from Meyer Werft in Papenburg and *Harmony of the Seas* from STX France at St Nazaire weighing in at 227,000gt with passengers and crew totalling over 9,000. Both ships are following in the Royal Caribbean tradition of providing novelty entertainment and technological innovation for passengers.

Passengers will be provided with RFID technology-enabled Royal WOWBands which can be used to enter cabins, purchase beverages, merchandise and anything else Royal Caribbean sells. Plus, WOWbands serve as an easy way to distinguish which muster station each passenger is assigned to. Also fitted is a high-speed internet experience known as VOOM, which is six times faster than any other Internet service at sea according to the company.

Those in inside cabins will have virtual balconies, where a high-definition LED screen offers floor-to-ceiling real-time views from specific points on the ship, including natural sounds that are piped into the cabin to provide as authentic an experience as possible.

Harmony of the Seas is powered by three 18,860kW Wärtsilä 16V46 16-cylinder main generator diesel engines and three similar Wärtsilä 12V46 12-cylinder engines producing 13,860kW each. The propulsion power will be provided by three ABB Azipod electric azimuth thrusters, and manoeuvring will be assisted by four 5,500kW Wärtsilä CT 3500 tunnel thrusters. The shipboard electricity will be supplied by two MTU 16V4000 emergency generator diesel engines. The propulsion system will enable the ship to sail at a speed of 23knots.

Ovation of the Seas has four bow thrusters with 4,694 horse power each, can travel at 22knots at cruising speed and has an engine output of 67,200kW.

After a successful pilot project on *Celebrity Silhouette*, *Ovation of the Seas* will join its sister ships in deploying a full air lubrication system. This system uses air bubbles to reduce the resistance between the ship's hull and the ocean, thereby increasing fuel efficiency. The new system – along with its newly designed podded propulsion system, bow thrusters, and fin stabiliser pockets – helps reduce resistance to the hull, increasing its fuel efficiency.

Building on the lessons learned from previous new ships, all incandescent lighting has been removed from *Ovation of the Seas* and the ship was designed and built to only use LED or fluorescent lights. This design feature will reduce the amount of energy consumed while producing the same amount of light emitted. In addition, LEDs and fluorescents also produce less heat, requiring less cooling in comparison to traditional incandescent bulbs.

Ovation of the Seas is one of the first cruise ships to be designed and built with a multi-stream exhaust gas cleaning system, or Advanced Emission Purification (AEP) system. The system is designed to treat exhaust gases created by the ship's generators, by injecting water into the exhaust stream and removing approximately 98% of sulphur dioxide emissions, 60-80% of particulate matter, and, as a by-product, some nitrogen oxides, although it is not designed to remove NOx.

The environmental officer onboard oversees operations to ensure compliance with the company's compliance policies, which include daily testing, monitoring, and recording of the AWP, AEP, and ballast water systems' and waste management performance.

Ovation of the Seas was built with an Advanced Wastewater Purification System that is designed to be twice as stringent as US federal standards for in-port wastewater discharge. In addition, *Ovation*'s AWP system will also be one of the first such systems designed to meet the new IMO special area requirements under MARPOL Annex IV (Sewage) for nutrient reduction.

The ship has been fitted with a ballast water treatment system in advance of the international requirements to have such a system. *Ovation*'s system will treat the ballast water both as it enters and leaves the ship, greatly reducing or even eliminating its potential to transfer non-indigenous species to local environments as it is expelled.

Another ship entering service this year is Holland America Line's *Koningsdam*, which has been built at Fincantieri's Marghera yard. At 99,836gt, the ship is 299.65m long, 35m across the beam with a draught of 7.95m. The ship has 18 decks, with passenger cabins totalling 1,331 and 588 for crew accommodation. With a service speed of 18knots, propulsion is provided by two pods of 14,000kW and three 2,200kW bow thrusters. The ship is classed by Lloyd's Register. *NA*

A new singing lesson

Concluding research on the potential risk of singing propellers has delivered a new methodology for design stage risk detection of the singing propeller phenomenon

Singing propellers, though rare, are a well-documented phenomena and problem for the marine industry that can considerably impact comfort levels onboard vessels.

In an effort to expand the industry's current understanding of the issue and how to avoid it, Wärtsilä and City University London have conducted a joint research project that has reviewed the industry's perception of the issue and pinpointed the specific design parameters that create risk of propeller 'singing'. This has ultimately revealed that the occurrence of the phenomenon is more complex than first thought, and spurred development of a new methodology that enables design stage assessment of the potential risk of singing propellers, allowing earlier identification of the problem.

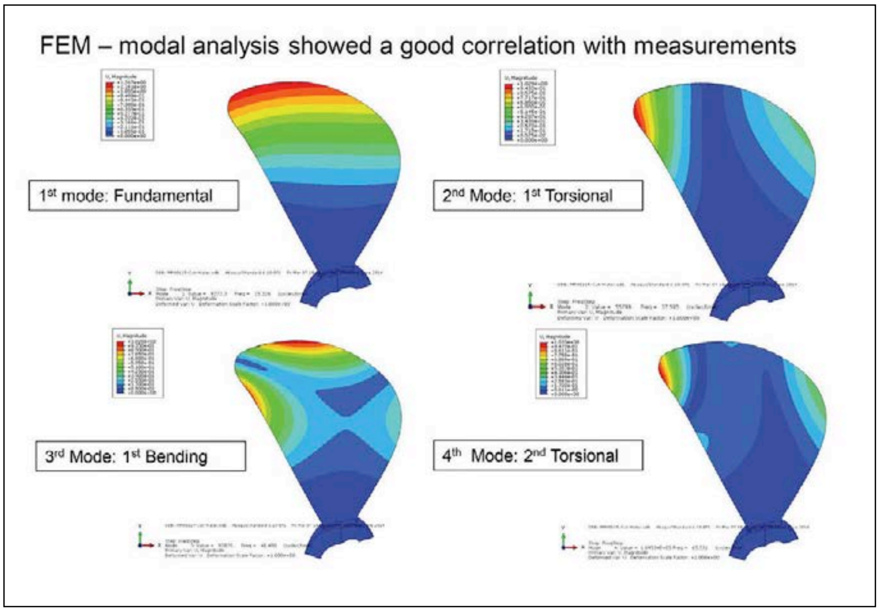


Figure 1: Propeller loads in testing

Bringing consensus

The project sought to develop and confirm a hypothesis clarifying the origins of singing and how to prevent it, and came in response to the fact that conventional treatments, namely, an anti-singing edge (ASE), did not always cure the singing in a direct and straightforward way for some advanced propeller designs.

Up until now there have been many exploratory studies, but no commonly accepted theory covering all aspects of the phenomenon, nor a commonly accepted remedy, says Wärtsilä. This resulted in a variety of views and a lack of consensus in the industry – although it must be added that there was general agreement regarding the important role of shedding vortices at the trailing edge of the propeller.

This uncertainty stemmed from the unique and peculiar sensitivities of the phenomenon, for example where singing can occur on one propeller where other propellers of the same design or series do not sing; there is singing of only one blade where other blades do not sing; where singing occurs after propeller polishing or cleaning; and singing that occurs temporarily while controllable pitch propellers (CPP) are reducing pitch.

A new investigation

So, in order to investigate the parameters more closely, researchers set out with the following hypothesis:

"Vortex Induced Vibration (VIV) is seen as the mechanism causing the singing phenomena. Eddies being shed from the trailing edge (TE) 'lock-on' in frequency and location with the natural response mode of the propeller blade. Non-singing propellers either do not show shedding of eddies at the TE or do not show the match between eddy shedding and natural mode (in frequency and location)."

The researchers found that the hypothesis proved to be workable and clarified the singing phenomenon, identifying the most important factors influencing the likelihood of singing. By means of confirmation of the hypothesis, results established three major findings:

1. Singing originates from the lock-on between vortex shedding at the trailing edge and the modal response from the blades
2. Singing or the potential of singing propellers can be discriminated from non-singing propellers (such as with a certain bandwidth) by an evaluation of flexural modes
3. Singing behaviour needs excitation forces in order to occur, and so in this respect, trailing edge and ASE details are very important and will determine whether vortices are shed or not.

Adapting work processes

Armed with this information Wärtsilä have changed their approach to singing propellers. Designs can now be analysed against a number of criteria whether there is a potential risk of singing, leading to identification of 'at-risk' propellers. Bert Oving, senior expert, hydrodynamics, Wärtsilä, says: "a newly developed procedure will be followed in which the insights, criteria and tools developed are used to reduce any risk of singing." This includes:

1. Following general guidelines -

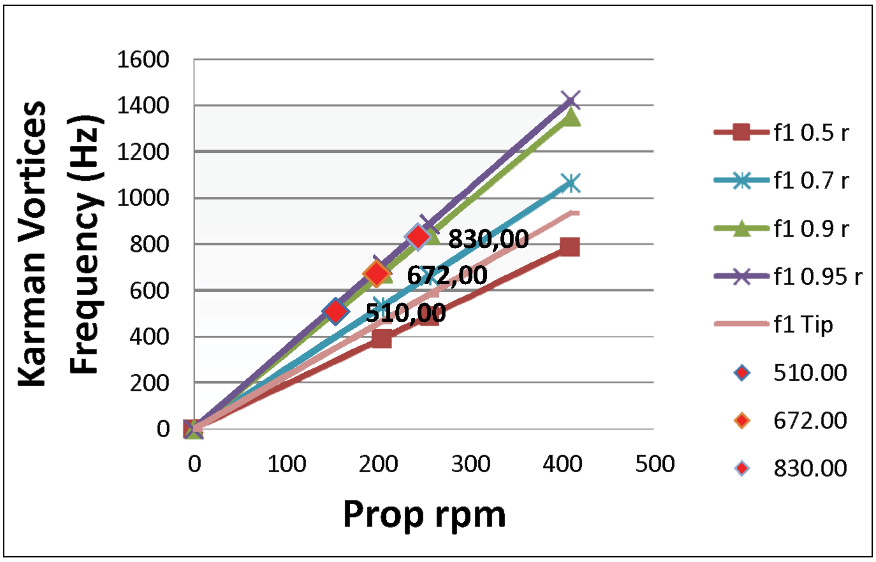


Figure 2: Calculated frequency of vortex shedding

these give direction on a number of parameters/characteristics

2. Evaluation of the flexural behaviour of the propeller design and checking against the developed criteria
3. Analysis of vortex shedding by numerical analysis

Vice president of propulsion, Wärtsilä Marine Solutions, Arto Lehtinen, says: "Our research has shown that the 'singing' phenomenon can be controlled by selecting the proper main parameters of the propeller blades, by careful attention to the flexural modes of the propeller blades, and by careful attention to the specific geometry at the trailing edge of the blades. It has shown that all these aspects are interacting and can prevent the 'singing' of the propellers."

The avoidance of singing has now been added as a standard Wärtsilä design feature and findings from the project have been worked into the company's procedures. Another important change in the propeller design procedure is the implementation of CFD as an integral part of the process. This OPTI-Design process was first launched in 2014.

Methodology

The study included CFD analysis of flow and vortex shedding at the trailing edge, as well as of the influence of cavitation; mechanical explorations, such as 3D measurements of geometries, vibration measurements in air and water, modal analysis using FEA and analysis of the impact of other affecting factors, including centrifugal hydrodynamic and centrifugal loads; parametric analysis and sensitivity studies; analysis of more than 55 Wärtsilä propeller records; and a literature survey.

Vibration measurements were taken on three test propellers using fibre optics (Fibre Bragg Grating sensors). This was both in water and air, and the excitation was applied on the hub. Modal analysis was then carried out that, according to Wärtsilä, showed a good correlation with the previously taken measurements. Findings from the measurement of propeller loads at different modes can be seen in Figure 1.

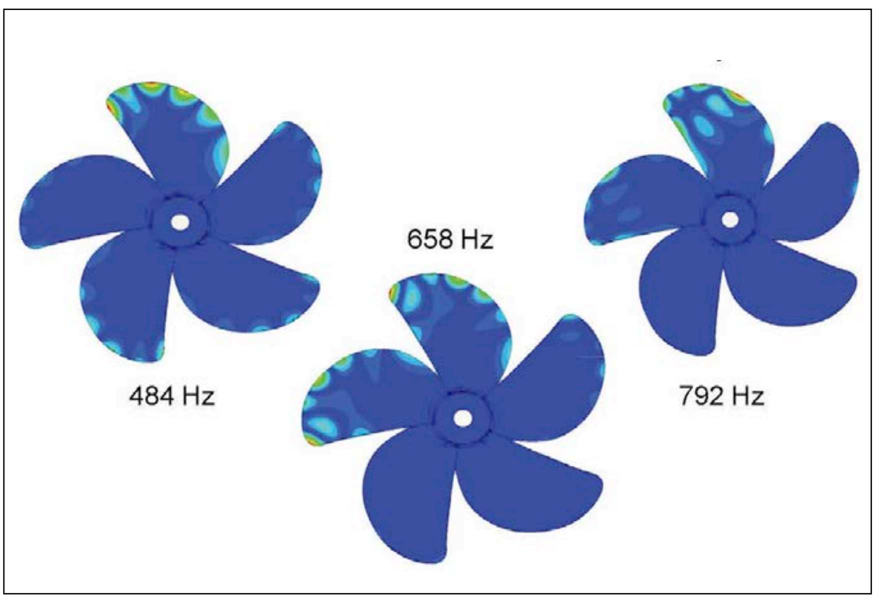
Vortex shedding and CFD

The first half of the project (2013) included measurement-taking and a study of modal response. Figure 2 shows the calculated frequency of vortex shedding depending on the propeller rpm and the actual radius (based on velocity and TE thickness), and that the recorded singing frequencies line up with excitations at higher radii (0.9r+). The accompanying pictures (Figure 3) show the natural modes at the singing frequencies of the three tested propellers. "It can be seen that vortex shedding at 0.9r+ lines up with displacements perpendicular to the TE," says Oving. "The match between both is the lock-on situation of excitation and response."

CFD analysis carried out in the second half of the study (2014-2015) illustrates the impact of trailing edge details on vortex shedding. In an example given by Wärtsilä, CFD results for an originally blunt TE (Figure 4) show vortex shedding behind the TE. However, CFD results taken after modification of the TE with an ASE (Figure 5) indicate that vortex shedding at the TE is no longer present.

The project began at the end of 2011 in cooperation with the City University of London as part of a PhD project. It concluded last December and the respective thesis is expected later this year. The joint project significantly adds to Wärtsilä's own internal study of more than 45 propeller designs for motor yachts and research vessels, which "showed further insights in parameters governing the 'singing' behaviour," according to the company, "[but] did not lead directly to a full understanding of root causes for 'singing'".

Figure 3: Natural modes at the singing frequencies of the three tested propellers



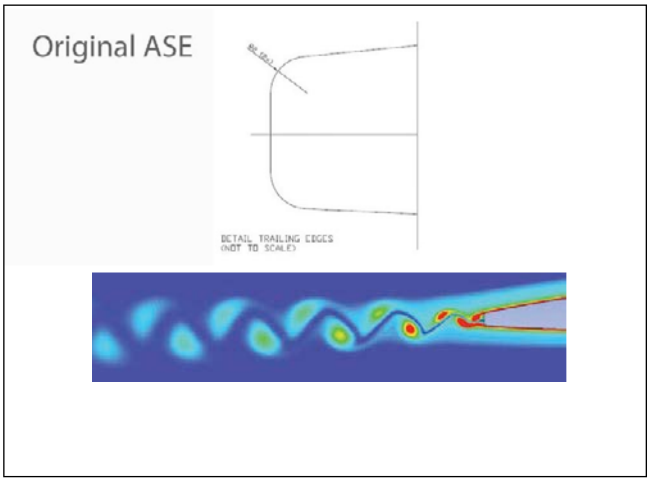


Figure 4: Vortex shedding behind the TE on a blunt TE

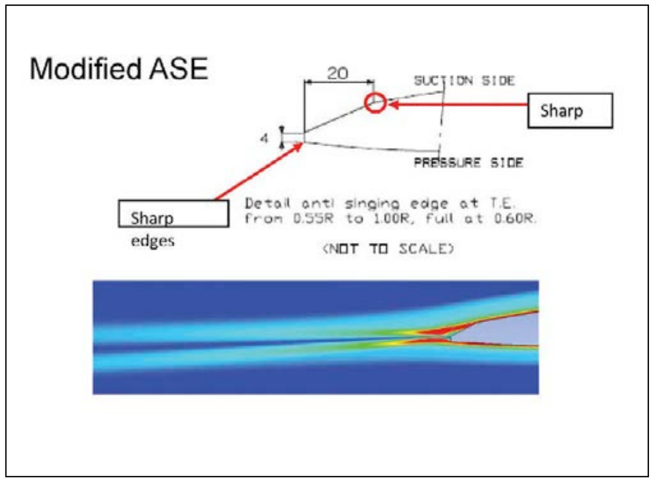


Figure 5: No vortex shedding behind the TE on a TE with a modified ASE

City University London's professor of marine engineering, Professor John Carlton, is quoted to say: "This has been an extremely successful project in dealing with an important propeller design issue. As an industry, we thought we had discovered a pragmatic solution to the singing propeller problem many years ago. However, some recent advanced propeller designs did not respond to the conventional treatment. As such, this research has now led to a method enabling designers to assess the singing potential of a propeller at the design stage." *NA*

Restructuring vibration absorption

Polymeric composites will improve vibration absorption onboard ships according to tests at the Krylov State Research Centre (KSRC). Valeriy M. Shaposhnikov, head of the structured strength division, and Boris A. Yartsev, head of the composite materials sector, explain their results

Polymeric composites can offer advantages when developing efficient vibration-absorbing structures for ships. These materials have a unique property: a higher damping capacity than conventional metals and alloys. Along with this, the layered structure of composites allows for a more efficient application of conventional viscoelastic materials, so composite vibration-absorbing structures are becoming of more and more interest. Such structures are manufactured in a single technological process and are consequently free of a number of typical drawbacks for metal-polymeric layered structures.

Naturally, the vibration-absorbing effect of these structures must be accompanied by other qualities, such as strength, stiffness, ease of manufacturing, moderate cost, availability to the market, etc. However, composite structures possess all of these qualities, and by virtue of being four-five times less dense than steel they have equal, and frequently even higher, strengths. In addition, the adjustment of dissipation & stiffness properties of composites could bring an extra gain in efficiency. This is because the change in stiffness parameter is known to lead to the change in frequency and shape of structural vibration. Accordingly, for specified external effects, it allows going out of tune with resonant modes. Composite elements of structures also offer more flexibility in controlling the spectrum of natural frequencies because their structural parameters, i.e. orientation angles and thickness of layers, are adjustable. This, in turn, leads to greater flexibility when controlling mechanical loss coefficients corresponding to these frequencies and when controlling the coupling of interacting vibration shapes without changing the composition of material. As a result, these advantages make polymeric composites highly promising in the development of vibration-absorbing structures for ships.

Vibration-absorbing structures aboard ships are exposed to various effects related to the dynamic character of loading and conditions of operation (temperature, humidity, etc.). These effects determine the set of requirements for the materials. To develop bearing structural elements, epoxy glass-reinforced plastics (GRPs) or carbon-reinforced plastics (CRPs) are used. GRPs have lower elasticity and strength than CRPs, but provide greater shock robustness and a cheaper alternative.

Vibration-absorbing elements of structures are made from polymeric compositions with high dissipative properties. Young's modulus E and mechanical loss coefficient η of polymers are significantly dependent on loading frequency *f* and ambient temperature *T*, so it is clear that vibration-absorbing polymers to be included in the composite structure must be selected with consideration of temperature and frequency conditions of the polymer's operation, i.e. $E=E(f_{ec}, T_{ec})$, $\eta=\eta(f_{ec}, T_{ec})$.

If the dissipation of the potential energy of straining is determined by normal stresses in the vibration-absorbing structural element, stiff polymeric compositions must be applied on surfaces of bearing elements. Such compositions are selected so as to simultaneously ensure the highest module of accumulation and the highest module of losses. Besides this, stiff composition must have necessary adhesion to the material of the bearing element. If the dissipation of potential straining energy is determined by shear cyclic straining of the vibration-absorbing element, it is preferable to use "soft" polymeric compositions arranged between bearing elements and covering layers. The main requirement of "soft" vibration-absorbing polymeric compositions is to achieve a mechanical loss coefficient that is as high as possible.

Vibration absorbing structures inside the hull

A two-cascade shock mounting with intermediate vibration-absorbing structures is known as one of the most efficient ways to reduce the vibration of power equipment aboard ships. Existing intermediate structures can reduce vibration at medium and high frequencies. For lower frequencies, corresponding to beam vibration modes, compound layered metal-polymeric structures are practically the only efficient way of damping vibration. The elements of such structures dissipate energy by a cyclic shearing of a thin layer of the viscoelastic elastomer installed between two stiff rigid layers. Maximum damping capacity in case of bending and, if some requirements to symmetry are met, of twisting vibration modes, is achieved when bending and twisting stiffnesses of bearing layers are equal. During this process, longitudinal vibration modes are not damped. To ensure the strength of metal-polymeric structures, additional elements must be installed between stiff bearing layers, making the structures stiffer and, consequently, reducing their vibroacoustic efficiency at lower modes of natural vibrations.

To overcome these drawbacks, KSRC (Krylov State Research Centre) experts suggested a number of composite structures that are intended for application inside the hull and have high dissipation properties: a box beam and I-beam (Figure 1*a*), a platform (Figure 1*b*), and two variants of an intermediate bearing frame (Figure 1*c*, 1*d*). These structures are two-layered and their baring layers are made of GRP with a vibration-absorbing layer of a stiff polymeric composition applied on the GRP surface. All these structures offer high damping (η_{min} = 0.1) starting with the first vibration mode. The indisputable advantage of such structures is the possibility to obtain similar coefficients of mechanic losses corresponding to different vibration shapes (bending, twisting, longitudinal).

Obtained results allowed development and practical application of a vibration-absorbing composite intermediate frame for a marine diesel-gearbox unit (see Figure 1*d*). This frame is basically a grating of longitudinal and transverse box beams. Box profiles consist of the bearing outer layer made of epoxy GRP with a vibration-absorbing layer of the stiff polymeric composition applied on its internal surface. The beams are stiffened with brackets from the inside, and additional brackets are installed where local loads occur due to fastening of shock mounts and power equipment. Vibroacoustic efficiency of the layered composite intermediate frame was determined by comparative tests of the frames made of different materials: composite and steel. It has been shown that a composite frame yields an additional vibroacoustic gain, $\triangle$L=6–19dB, at resonant frequencies.

Vibration-insulating couplings

A massive transition to low-frequency shock mounting of ship power plants triggered the R&D activities regarding elastic vibration-insulating couplings that not only transfer torque but also compensate significant mutual misalignments of the shafts they connect. This led to the development of composite elastic couplings, which have

Figure 1a: A composite box beam and I-beam

Figure 1b: A composite platform

a number of advantages compared with conventional ones, i.e. those without polymeric materials. These, above all, include low cost, light-weight and high vibration insulation offered by polymeric materials thanks to their being less dense than metal ones. Such features allow for the development of composite coupling designs that meet key requirements i.e. maximum strainability in all directions with guaranteed transfer of required nominal torque. Existing elastic composite couplings ensure the transfer of nominal torque $M_{T\ nom}$ [5 kNm, 400kNm] with simultaneous compensation of shaft misalignments ($\triangle_{max}$=10–20mm). However, the drawback of these couplings is their low vibration absorption (η_{max}=0.01). This has meant that the challenge to develop new elastic coupling designs which are made of polymeric composites and offer better dissipation has become especially relevant. For a variant of such structures, see Figure 2.

Figure 1c: First variant of an intermediate bearing frame

Figure 1d: Second variant of an intermediate bearing frame

Figure 2 shows a composite vibration-insulating coupling that consists of two three-layer membrane rings (1) connected with an intermediate shaft (2). These membrane rings respectively consist of stiff outer layers, a bearing external layer (3) and covering internal layer (4), connected by a layer of a soft vibration-absorbing polymer (5) with a thickness of up to 10% of the thickness of the stiff outer layers. There is no link between the internal edge of the stiff covering internal layer and the driving or driven shaft, so stiff outer layers of membranes can perform mutual linear and angular movements.

Experimental studies allowed defining a composite vibration-insulating coupling as a non-linear elastic coupling with stiff loading parameters. Mechanical loss coefficients at axial, radial and bending vibrations are $\eta_L \approx \eta_R \approx \eta_D \approx 0.25$. For twisting vibrations, $\eta_T \approx 0.08$.

The results described above show that non-classic properties of polymeric composites will be advantageous when developing vibration-insulating structures for ships, offering considerably higher energy dissipation than any of their existing prototypes. As a result, these structures will significantly improve the habitability of ships, reducing noise and vibration. *NA*

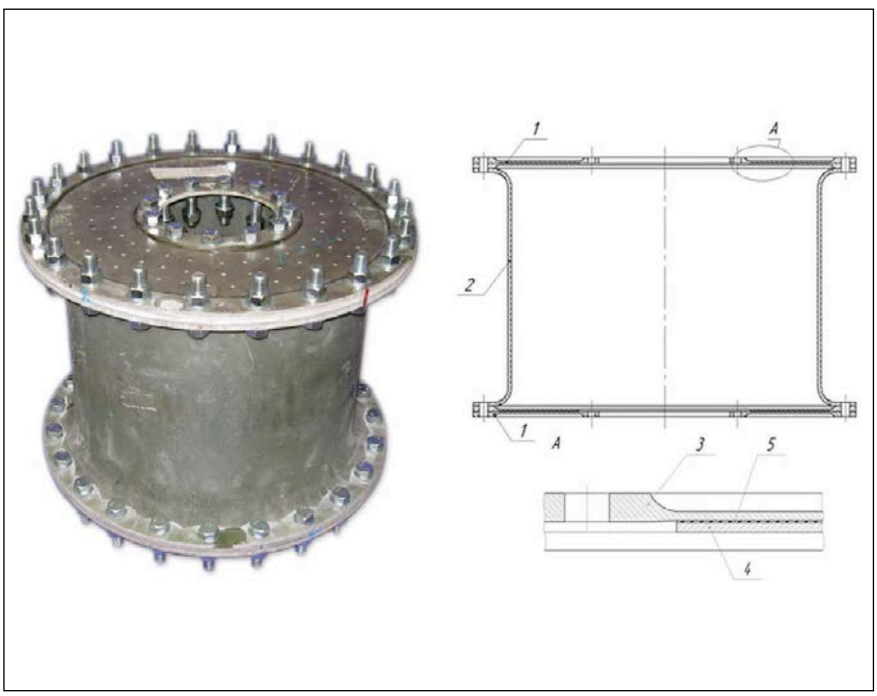


Figure 2: A composite vibration-insulating coupling that consists of two three-layer membrane rings

Powering through

A new Ramform Titan-Class vessel has been delivered despite challenging economic circumstances for the gas & oil exploration market

Ramform Tethys has received a power boost, strengthening its redundancy

Petroleum Geo-Services (PGS) has continued to expand its fleet in the midst of 28 seismic vessels ending up stacked or scrapped since 2013, offsetting the current downturn with continual investment in top of the line vessels.

The company intends to set the standard for seismic operations for the next 25 years with its latest $285 million investment in the future of marine seismic, *Ramform Tethys*, one of its highly equipped Titan-Class vessels.

Ramform Tethys was delivered to PGS on 16 March and will head for operation in Europe. It was built by Mitsubishi Heavy Industries Shipbuilding Co.(MHI) in Nagasaki, Japan, and is the third in a series of four Ramform Titan-Class vessels to be built for the company, which offers marine seismic and electromagnetic services and products.

The vessel has a delta-shaped design and Roar Ramde developed the vessel's hull form. Norway-based Yran & Storbraaten designed the superstructures and interior, while Vard ship design provided the initial design and MHI the detailed engineering.

In comparison with preexisting Titan-Class vessels, PGS has upgraded the generators on *Ramform Tethys*, adding an additional 1,680kW of power to each of the twin engine rooms. The power plants are mutually redundant and are equipped with six engines that deliver 26.4MW in total. This enables the powering of three 6,000kW controllable pitch propellers and provides a healthy redundancy, according to the company.

"The vessel's propulsion system consists of three fully independent CPP main propellers in nozzle, each at 6,000kW" says Robin Tomren, technical manager, operations, maritime, PGS. "Each propeller is direct[ly] driven by a double winded electric motor [at] 0-125rpm, [and] is fed by two fully independent frequency converts. Each propeller is placed in fully segregated compartments [to provide the] best redundancy. Each propeller [has] one flap rudder with independent steering gear also fully segregated. In addition to the three main propellers, [there is] a retractable thruster in the bow that can contribute to propulsion and manoeuvring. The vessel's power plant consists of six main engines, segregated in two fully independent engine rooms. Each engine room has fully segregated auxiliary systems, as this gives a high level of redundancy for the vessel."

A fuel efficient acquisition speed of close to 5knots can be maintained while towing multiple sources and 15km of submerged recording and positioning equipment. The company projects that a vessel can remain at sea for 90-100 days while operating a full recording array, which can make an important difference to project safety margins and profitability. This can be especially helpful when operating in remote locations where fuel sources are scarce, and also adds environmental and safety-based benefits; large efficient operations shorten vessel hours, cutting risk exposure and emissions.

The vessel is 104m long and 70m wide at the stern, making it one of the largest seismic vessels delivered.

Tomren notes that "A width of 70m is not common for a vessel, and when the length is only around 100m…a quite special hull shape [is required].

As a result, he continues: "A lot of effort was made to understand the vessel motions and accelerations in different sea states. The vessel has the transverse metacentre approximately 86m above baseline. The theory behind this subcritical roll period is that the energy in the waves with this frequency is so small that it nearly has no impact on the vessel. This has also been proven in full scale with the sister vessels *Ramform Titan* and *Ramform Atlas*."

Ramform Tethys' back deck houses 24 streamer reels, each with a 12km capacity for dual-sensor streamers. It has a row of 16 reels across the stern and 8 reels further forward.

The vessel's 24 reels and massive back deck have other operational advantages, including capacity to carry out running maintenance of sources and streamers, or re-configure the spread between projects.

Per Arild Reksnes, EVP, operations, says: "With the increased power output and the back deck modifications we are enhancing the Ramform Titan-class acquisition platform further. Productivity, safety, stability and redundancy are the key benefits of these vessels. Their ability to tow many streamers gives high data quality with dense cross-line sampling and cost efficient acquisition with wide tows."

The state of play

28 seismic vessels have been stacked or scrapped across the industry since 2013, starting with those at the wrong end of the industry cost curve, according to PGS. The current vessel retirement rate has therefore accelerated because of the downturn, driving efficiency measures. In response, PGS is "retooling for the future" and is scheduled to deliver a further Titan-Class vessel in the first quarter of 2017.

At the current market price, the US$285 million investment in *Ramform Tethys* will take longer to recoup than its predecessors. However, PGS is optimistic that the level of technology onboard and the flexibility the Titan-Class vessels provide, which can range from reconnaissance exploration surveys to providing the detailed resolution required for the production of 4D seismic data, will continue to strengthen its provision and consequently business.

They believe that *Ramform Tethys* is well adapted to the current economic climate with low operational costs per streamer and high quality production from the dual-sensor, broadband GeoStreamer data it produces.

Jon Erik Reinhardsen, president and CEO of PGS, adds: "In the current challenging market environment we also experience more demand for our best capacity and *Ramform Tethys* will add to PGS ultra-high-end value proposition."

The entire PGS fleet uses GeoStreamer, PGS' broadband system for measuring marine seismic. Approximately 60% of the fleet has ultra-high-end Ramform vessels, while 40% of the fleet is made up of top of the line Ramform Titan-Class vessels.

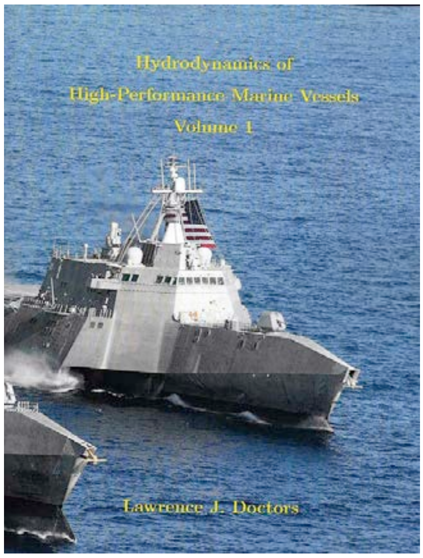
According to PGS, market indicators suggest that seismic surveys will continue to get larger as the industry will continue to economise while searching for new energy reserves. In this way, the company expects the network of towed equipment to continue to widen and lengthen, and believe it is likely the number and type of equipment units deployed will also continue to grow as new technologies and survey methods come to the fore. *NA*

Tethys has 24 streamer reels and can tow up to 15km of dual-sensor streamers from each of them

Hydrodynamics of High-Performance Marine Vessels

Reviewed by E.C. Tupper

Hydrodynamics of High-Performance Marine Vessels
Written by Lawrence J. Doctors, published in two volumes and available through Amazon.com. as softcover books, 2015. Vol 1, 449pp, ISBN-13: 978-1512244717, £75.99. Vol. 2, 438pp, ISBN: 13-978-1514839430, £75.83.



The author is a highly respected naval architect and will be well known, at least by reputation, to most of our readers. He graduated from The University of Sydney with a first-class honours bachelor's degree in Mechanical Engineering in 1965 and a Master of Engineering Science degree in 1967. He went on to study Naval Architecture and Marine Engineering at the University of Michigan and received a doctorate in 1970. Since 1971, he has taught at The University of New South Wales (UNSW) and was Coordinator of the Naval Architecture Program for the Bachelor of Engineering degree at UNSW from 1985 to 2004.

Most of Professor Doctors' research efforts have been devoted to numerical ship hydrodynamics, centred on the study of advanced marine vehicles such as those covered by this book. He has published over two hundred and twenty research papers and reports on these topics. He has been a regular contributor to, and reviewer for, RINA journals and conferences. He has spent periods at the David W. Taylor Naval Ship Research and Development Center, Tel Aviv University, the University of Michigan, the Australian Maritime College, and Strathclyde University.

"Hydrodynamics of High-Performance Marine Vessels" is a comprehensive two-volume book devoted to the analysis of common types of high-speed marine vessels which may also be referred to as advanced marine craft. Included are monohulls, catamarans, trimarans and other multihull vessels, air-cushion vehicles, surface-effect ships and planing craft. There are separate chapters on each of these types of vessel. As an example, for air-cushion vehicles the lift systems, wave resistance experiments, non-linear effects and optimisation are covered. A separate chapter deals with skirts and seals, including bow finger seals and stern lobe seals.

The hydrodynamic aspects dealt with for these craft are the steady-state resistance, wave generation, sinkage and trim, including shallow water effects; unsteady effects on resistance and wave generation; motions in waves. For motion response in waves separate chapters deal with displacement vessels and non-displacement vessels. For displacement vessels – monohulls, catamarans and trimarans – frequency-domain strip theory, sectional hydrodynamic coefficients and numerical aspects of response in a seaway are covered. Separate chapters are devoted to viscous resistance, transom sterns and the behaviour of skirts for air-cushion vehicles and seals for surface-effect ships. Effects of the finite depth of the water and the possible lateral restriction on the width of the waterway are covered.

For each topic, the presentation includes a full analytical development of the theory accompanied by comparisons of theoretical predictions with extensive experimental data. This gives the reader a great deal of confidence in the theories presented. Unfortunately, hydrofoil craft, which were an early example of high speed craft gaining lift from hydrofoils, and Wing-in-Ground (WIG), used extensively by the Russians, vehicles are not included. I understand this is because of lack of space and clearly the author had to draw a line somewhere.

The hydrodynamic theory chapters deal with deep water and shallow water, viscous resistance, including artificial reduction of skin friction, aerodynamic drag and transom sterns. Thus there are two main "themes" in the book; the hydrodynamic theory and the description of specialised vessels. The author has managed to integrate both themes very successfully.

No specialist theoretical work can be said to be easy reading, but the material is presented clearly and in an easy-to-follow manner. There are 433 photographs of ships and ship models in total with 1,155 graphs, 1,295 equations and 1,249 references. The extensive bibliography, very useful in its own right, runs to 76 pages. I understand it was printing needs that dictated the two volumes, but both are needed as notation is in Vol. 1 while terminology and the comprehensive bibliography and index are in Vol. 2.

The work represents the author's experience of more than fifty years in various universities and research centres. It is good that the author has been able to condense that experience into two volumes, and it can be highly recommended for the readers at which it is aimed, university-level students and specialised industry engineers in the maritime field. *NA*

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A comment on the Doughnut Tanker

Dear Sir,

I read regularly with interest your excellent magazine '*The Naval Architect*', normally without comment. However, the article and content on the Doughnut Tanker did give me pause for thought. I have only been involved in some coastal LNG carriers of 3,200tonnes where the tanks and gas handling equipment was designed, supplied and installed by the equipment supplier. We only then had to be very accurate with the interface of the cylindrical tanks with the ship's hull.

With this in mind I would comment on the above article and its claims, especially Table 1, as follows:

1) I can see the advantage of cubic tanks taking up the void spaces that inherently surround spherical and other circular shapes. It would have to be asked however why something so logical has not been done before? The question then follows, is a cube shape tank, which the industry has not accepted before, safe and suitable for the operational parameters of LNG carriers loaded and unloaded?

2) Unless the rules have somehow changed drastically, increased cargo capacity claimed for CDTS will increase gross tonnage (GT), not 'significantly reduce it' as stated by the authors.

3) Table 1, unless I am seriously missing something, is not presented in a way that supports very well the authors' claims. If we calculate the metric block coefficient and get an indication of gross tonnage from the dimensions and cargo capacity given in the table we arrive at the results seen in the table below for each vessel type.

This suggests to me that the increased cargo capacity and hence gross tonnage claimed is achieved by simply having a fuller hull, tending towards a rectangle, which does not really lend itself to reducing power for a given cruising speed.

However, if one reduces the gross tonnage for the CDTS in the ratio of its block coefficient and that of the membrane type, the CDTS GT becomes 66,000tonnes. This then would represent a bit more realistically the potential gain of say 10% in cargo capacity, which is more readily acceptable since you are employing the void spaces inherent in the other designs.

4) In passing I wonder if the beam of the vessels chosen was intentional, as it is the maximum beam permissible (49m) for the 'New Panamax'. It will obviously also suit Suez providing the 'air draft' does not exceed 68m in any condition.

In closing I would recommend the authors compare 'like with like', as that is what ship owners will look for. There is a big difference between academia and the professional world where the risks are. But it then seems a pity if a potentially good idea suffers from poor presentation and not realising business is solely about guaranteed operational success and profit.

Item	Spherical	Membrane	IHI SPB	CDTS
Block Coeff	*0.73*	*0.79*	*0.80*	*0.89*
Approx Gross Tonnage	*55,000*	*60,000*	*60,000*	*74,000*

Yours faithfully,
Clifford Thew,
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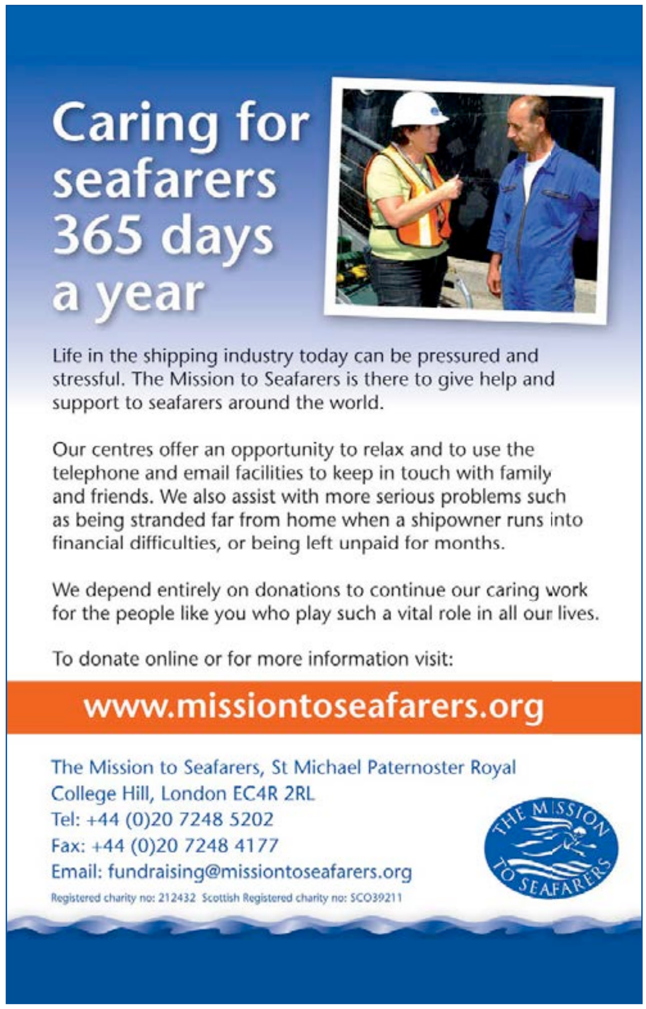
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