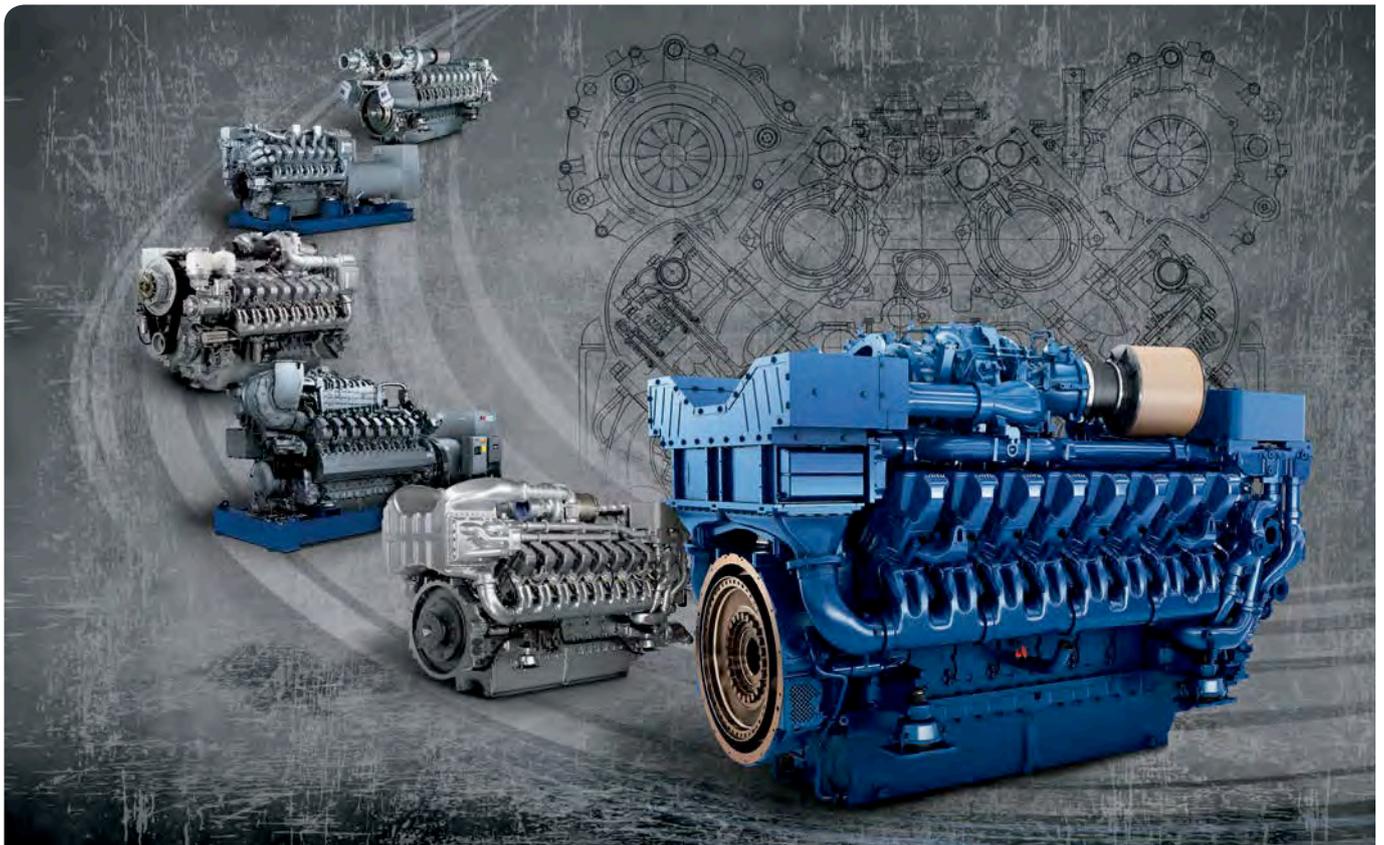




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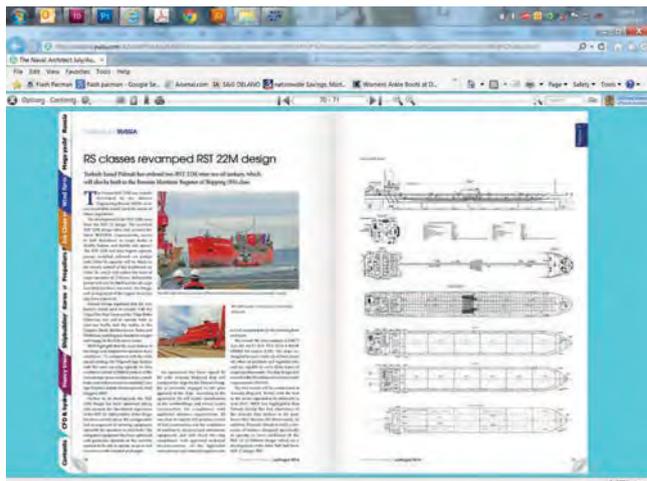
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Installing cyber security at the newbuilding stage

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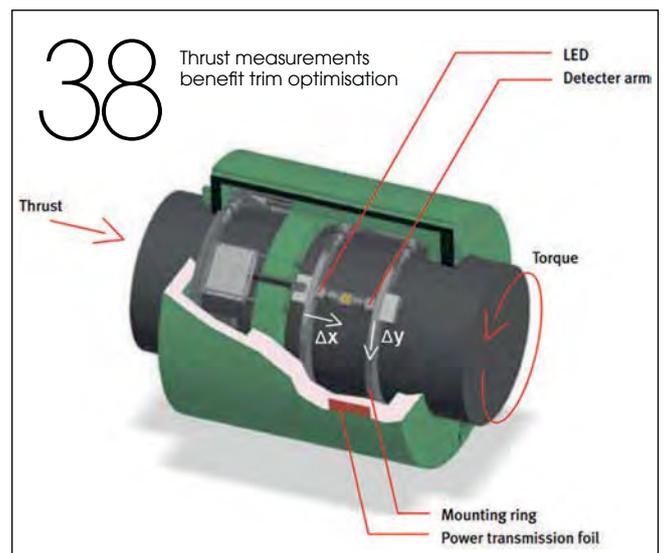
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European shipbuilding's 'renascent' orderbook

Fincantieri's Vard facility in Norway is currently building a series of luxury expedition vessels for Ponant

Perhaps I should whisper it quietly, but while this year's Posidonia event was a lively event as a newcomer I couldn't escape the impression that many of the big marine technology players were holding back their major announcements for SMM in Hamburg in September. One would surmise that it's simply a reflection on Greek shipping in general – last year Greek magnates accounted for 23% of all second-hand vessel sales – but the focus was very much on the retrofit markets and the quandaries of whether to install scrubbers and the best choice of ballast system (see News Analysis p.12).

But there were other talking points and of course the fluctuating fortunes of global shipbuilding are always a rich topic. At a press briefing Knut Ørbeck-Nilssen, CEO of DNV GL – Maritime, presented data from Clarksons Research that indicated the European orderbook is now worth more than China. Continuing a growth trend that began in 2010, up to May this year US\$62.1 billion (a 29% share) had been placed in Europe, compared to \$US60.3 (28%) in China.

Ørbeck-Nilssen said: "We're seeing quite a remarkable renaissance in European shipbuilding. This is not just the big cruise yards but many of the smaller yards. What is driving this is the more complex type of vessels, not only cruise but also the more advanced wind service vessels, expedition vessels and also some in the gas-fuelled ships."

One can understand, of course, that it's in DNV GL's interest to favour Eurocentricism but anybody with any understanding of the global market will realise it's all relative to the prolonged downturn in orders in the traditional sectors. The oversupply of tonnage for crude and product tankers and

reduced, albeit slowly recovering, dry market has hit China and South Korean yards much harder than the high-end specialists.

Moreover, shipowners have been mired in so much uncertainty about the future. Speaking shortly before Posidonia, at the advance press conference for SMM, Clarksons' doyen Dr. Martin Stopford opined that many were "sitting on their hands" because they were uncertain what strategy to adopt. One could argue owners should bear some of the responsibility for the chicanery that has afflicted rollout of the Ballast Convention and the 2020 sulphur cap, rather than blaming IMO member states (see News p.10).

But notwithstanding environmental regulations and doubts regarding what fuels might be available and how much they will cost, there are the more convoluted questions surrounding Smart Shipping. In this regard one does begin to wonder whether the tail is wagging the dog here, that the sophistry of 'efficiency' is sometimes being used as a carrot to cajole owners into adopting new technologies that represent only marginal gains when it comes to the primary function of transporting goods, or in the worst cases prove entirely defective. Stopford made the case for a 'keep it simple, stupid' step-by-step approach and called for a 'Smart Shipping Toolbox' to help owners plan for the future effectively.

Conversely, there's no question that technology has proven a boon to the European shipyards and opened up much-needed new markets, particularly since the offshore slump. I recently returned from a trip to Ålesund, Norway, where the expertise developed from years of offshore ship construction has been repurposed in the building of high-end

polar expedition vessels. At Fincantieri-owned Vard's facilities the second of a series of six expedition ships being built for the French luxury cruise operator Ponant is currently under construction (a seventh vessel, with icebreaking capability, is also on order). Tore Ulstein, chair and deputy CEO of shipbuilders/designers Ulstein Group, had a very similar story to tell about the fortunes of his company. Personally, I'm a little uneasy about expedition vessels and operators' marketing claims that such trip help promote environmental awareness, but it's a testament to their adaptability that these companies continue to thrive while their core offshore market remains so quiet.

Another company which has had to adapt to offshore's decline is Rolls-Royce Marine, although it shows little sign of slowing down on research and development projects. One of the highlights of a packed day of presentations came from Oskar Levander, SVP for Concepts and Innovation (and no stranger to regular readers of *The Naval Architect*), put forward the intriguing suggestion that the key to hitting IMO's future CO₂ targets could be slow-steaming unmanned vessels powered in part by wind (a topic we will return to next issue).

Rolls-Royce Marine has been at the forefront of such research but, with the division in the midst of a 'strategic review' due for completion at the end of this year, it's interesting to speculate what might happen if it found itself with a non-European owner seeking to incorporate and assimilate its expertise into ship design and construction in Asia. While not in itself a move that would drastically shift the current balance of the orderbook it's naïve to imagine high-end ship construction will be monopolised indefinitely by Europe. *NA*

Satellite communications

Inmarsat releases Industrial IoT: Maritime report

As part of the Inmarsat Research Programme 2018, the satellite company has released a set of reports ‘focused on understanding the ways that the industrial Internet of Things (IoT) is affecting the global supply chain’ across a number of industries.

Data was gained from company surveys, with answers scored across six areas: adoption, skills, security, data, connectivity and IoT technologies, and investment. Depending on a company’s score in each area, they were then placed into one of the Inmarsat Industrial IoT Readiness Tool’s four categories: laggard, starter, progressive or leader.

Within maritime, 6% of respondents were from the Americas, 55% from EMEA, and 38% from APAC. Taking a broad view of ‘what is the maritime sector’s overall IoT readiness’, the report suggests that the largest category consists of starters, at 34%. This is followed by laggards at 28%, progressives at 26%, and leaders at around 15%. Benchmarked against the average for all sectors, maritime has a higher number of both laggards and leaders, and a lower number of starters and progressives.

The report claims that IoT-based solutions are a way for industry to get ‘its house in order in response to rising environmental concerns, their use to enhance health and safety, and potential to improve efficiency’. However, it points out some of the barriers to adoption, claiming that there is a ‘lack of in-house skills and industry knowledge, but also entrenched ambivalence towards new technologies’.

The skills gap in particular is highlighted by the fact that 45% of respondents have been deemed laggards in this area, claiming shortcomings related to decision-making and planning skills. Other notable percentages include the 55% of starters when it comes to IoT security – perhaps due to nascent fears over cybercrime and the vulnerabilities of connected vessels – and over 60% of starters in relation to the maritime sector’s approach to data.

Inmarsat president Ronald Spithout



Conversely, the report does identify a large number of progressives (approx. 55%) with regard to IoT investment, with IoT technologies seen as the number one next generation technology that maritime companies expect to invest in over the next three years.

Autonomous ships

ClassNK publishes autonomous guidelines

Japanese classification society ClassNK has published ‘Guidelines for Concept Design of Automated Operation/Autonomous Operation of ships’. This set of guidelines focuses on procedures for evaluation and approval of the concept design of automated/autonomous operation to ensure safety.

Application of the guidelines depends on the automation of so-called “decision-making subtasks,” to be performed by automated operation systems. These are defined as ‘subtasks related to human decision-making, such as situation awareness, decision and action. The decision-making subtasks are executed based on external information and events acquired through sensors, etc. in general.’

The guidelines stipulate the clarification of the division of roles between human and automated operation systems, the operational design domain, fallbacks (if automated operation systems malfunction), human-machine interface, cybersecurity, and reliability of computer systems. The structure of the risk assessment to be applied to the above is also included, as well as a list of documents to be submitted for concept design approval.

At present, the guidelines are labelled as a ‘provisional version’ owing to the high likelihood of further design developments, and are as such non-prescriptive. The guidelines can be downloaded free of charge by registering for ClassNK’s ‘My Page’ service, via the class society’s website www.classnk.com and clicking on the ‘My Page Login’ button.

Bulk carriers

JMU improves bulker design despite effect of regulations

Japan Marine United (JMU) revealed the most efficient iteration to date of its J-Series kansarmax bulk carrier design at the Posidonia exhibition in June, intended to overcome the “negative impacts” of new regulations.

Whilst JMU praised the string of policies that have recently come into force or will do so in the near future, they noted their “significant effect [...] on ship design,”

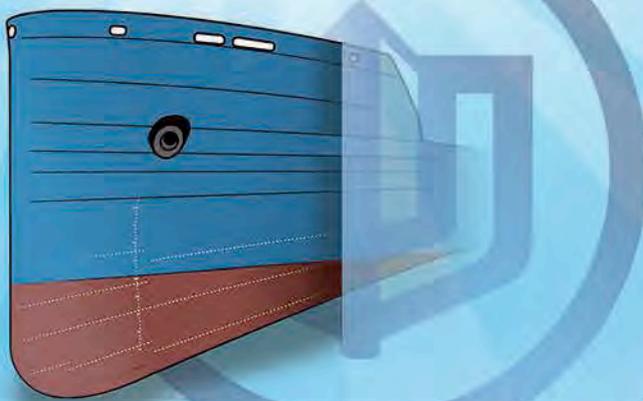
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singling out the NOx Tier III regulation and the global sulphur cap. These, the company claimed, will require the installation of “very large equipment,” meaning “hull silhouette shall be increased significantly. These are negative impacts on economical ship design.”

To mitigate these impacts, JMU has undertaken a programme of hull form optimisation, informed by model tests in its own basin. It has also applied a number of in-house technological solutions designed to save energy, including a Super Stream Duct, which recovers energy lost via longitudinal vortices at the stern by generating thrusting forces, a SURF-BULB, which converts the rotational energy behind the propeller into thrust, and an L.V.Fin, which reduces hull resistance by straightening the stern flow. A new propeller shape has also been adopted.

These design features not only cancel out the effect of regulations, but achieve improvements compared with previous J-Series designs. Without such technologies, new regulations would have caused a 1% reduction in deadweight, 2% shrinkage in possible cargo hold capacity, and an increase in fuel consumption of 5%. However, when applied, these technologies generate increases of 3% and 4%, and a reduction of 5% respectively, leading to overall improvements of 2% in deadweight, 2% in cargo hold capacity, and 1% in fuel oil recovery, as compared with the previous J-Series kansarmax bulk carrier. JMU also quoted an EEDI 20% lower than the baseline.

The vessel design further features a dedicated ‘scrubber ready’ space in the engine room to smooth installation of the technology, if adopted.

Research funding

Horizon Europe proposal includes maritime

The European Commission’s proposed iteration of its next Horizon Europe research and innovation funding programme, which supports research tackling societal challenges, will include the ‘Waterborne Sector’, opening up the maritime sector to significant funding.

The Horizon Europe proposal is aimed at the 2021-2027 EU budget, and contains three ‘pillars’ including ‘Open Science’, ‘Global Challenge and Industrial Competitiveness’ and ‘Open Innovation’. The second pillar, set to receive the largest amount of funding, includes five clusters, of which one is ‘Climate, Energy and Mobility’, with access to an annual budget of €2 billion. It is within this cluster that the ‘Waterborne Sector’ sits.

The Shipyards’ & Maritime Equipment Association, SEA Europe, which represents almost 100% of the European shipbuilding industry, recently welcomed the larger budget for the funding programme, as well as

the inclusion of the ‘Waterborne Sector’ in the ‘Global Challenger’ pillar, stating: “This approach acknowledges that our sector is confronted with a series of global societal challenges, such as climate change, digitalisation of shipping and logistics operations or exploiting the oceans in a sustainable manner.”

Looking forward, SEA Europe further stated: “it is now essential to persuade EU policy-makers in the next period that our sector is essential for the future of Europe as well as for Europe’s global maritime and marine leadership.”

Emissions control

Trade associations demand action on sulphur issues

Trade associations BIMCO, Intercargo, Intertanko, the International Chamber of Shipping (ICS) and the World Shipping Council (WSC) called upon IMO and its member states to ‘make progress on key challenges around the global sulphur cap to avoid compromising safety or unfairly penalising individual ships’ in a joint statement published on 18 June.

The statement is intended to urge progress at the Intersessional Meeting on consistent implementation of regulation 14.1.3 of MARPOL Annex VI, part of the Sub-Committee on Pollution Prevention and Response, held 9-13 June.

It accompanies five submissions to the IMO in the form of papers on a draft standard for reporting on fuel non availability; a call for member states to take a pragmatic approach when verifying compliance with the cap and a format for implementation plans; the safety implications and challenges of 2020 fuels; verification issues and control mechanisms; and proposals for amendments to MARPOL Annex VI requiring sampling points for fuel oil.

Although the signatories welcome the environmental benefits of the cap, they note that ‘worldwide implementation of this game-changing new regulatory regime will be far more complex than the previous introduction of sulphur Emission Control Areas’, pointing to issues of fuel quantity and quality, with some blended fuels predicted to fall outside the ISO 8217 standard. This may lead to ‘potentially serious safety issues’, the statement claims.

In view of this, the statement urges pragmatism from port state control authorities ‘during the initial months of the global switchover’, which may see some shipowners struggle to prove compliance due to a lack of ‘compatible’ and ‘legally compliant’ fuels in worldwide ports, despite there being no legal transitional period. [NA](#)

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Support for scrubbers grows as safety fears surface

Whether or not to install scrubbers was a hot topic at Posidonia, as shipowners continue to stall. However, with the safety of blended fuels uncertain, scrubbers may yet boom, writes Malcolm Latache

Posidonia has always been more synonymous with partying and taking an optimistic outlook on shipping than a launching ground for new technologies and by all accounts this year's event in early June was not a departure from the norm.

Nevertheless, the discussions and debates in Piraeus and just about everywhere else at the present are centred around the best way of meeting the impending 2020 rules on sulphur levels in fuels – although the effect of President Trump's tariffs and trade wars is coming a very close second and gaining ground.

The old talking point of how best to deal with the ballast water treatment problem is beginning to move off the radar as more systems gain US Coast Guard type approval. This June three systems – Techcross' Electro-Cleen, Samsung's Purimar and Bio-UV's Bio-Sea B – were added bringing the total of US approved systems to nine and a further six systems are awaiting approval having completed all testing and submitted their applications.

Fittingly, news of the Techcross approval came during Posidonia allowing the company to boast of its achievements but Samsung missed the boat with its approval coming a week after the show closed and Bio-UV's the following week. A notable feature of the Techcross and Samsung approvals is that the systems involved are quite high capacity. Along with the Ecochlor system approved last August all three have models with maximum flow rates of 10,000m³/h or above making them suitable for a much wider range of vessels especially larger ships although perhaps not the largest unless twin systems are installed.

Despite the fact that the 2020 deadline is drawing ever closer and the time for making decisions as to how to meet it is fast running out, shipowners generally do not seem to have formulated plans for putting into action in time. Coinciding with Posidonia, US classification society ABS issued an advisory on fuel choices that reported a recent survey it had carried out showing 53% of shipowners are still undecided as to their 2020 strategy.

Although most existing ships will, at least in the short term, be obliged to run on some form of compliant fuel, for new vessels there appears strong support for both scrubbers and running on LNG or some other alternative fuel. Determining exactly how many ships will have scrubbers in advance of the deadline is not the easiest

task. Estimates suggest that the figure could be around 2,000 to 2,500 by 2020 but others think the eventual numbers will be considerably higher.

Around a year ago it was reported that some 60% of newbuildings suitable for scrubber installations were being ordered either with a scrubber to be installed or to be 'scrubber ready'. To these the almost 1,000 or so vessels already fitted with some scrubbing capacity, and any that are retrofitted between now and 2020 or soon after, can be added.

Covering many topics in four hours at Posidonia, the BIMCO Power Panel could not devote huge amounts of time to the debate on scrubbers, but bankers, class and shipowners all spoke in favour of installing them as a strategy for suitable ship types. A boost for both scrubber makers and those considering installing them was provided by Henriette Brent-Petersen, MD and Global Head of Shipping and Offshore Research at DVB Bank, who said that arranging finance should not be a problem.

That sentiment has been echoed by others recently with some analysts pointing out that since the payback period for a scrubber might be measured in months rather than years, even installing one now knowing that in a few years' time regulations may make them less attractive could be a good bet with the capital cost being more than recovered before any restrictions could be put in place.

Less than two weeks after Posidonia, the shipping industry was making its case in advance of the special July intersessional meeting agreed by PPR5 earlier in the year. A statement issued by a group of the leading industry bodies including BIMCO and ICS, highlighted the safety issues involved in implementing the 2020 rules (see pp.8).

In 2015, ships trading in ECAs primarily changed to ISO 8217 distillate fuel oils. But in 2020, as well as using distillates to comply with the 0.5% sulphur cap, many ships will have to use blended fuel oils and new products which are outside of the ISO 8217 standard. Exactly how compatible different fuels will be is an unknown factor and if ships are obliged to mix fuels the results could mean ships suffering power outages at any time. Since the formulas for some of the new fuels are still to be decided, even the makers of them are not in a position to offer guarantees on miscibility.

At least those owners with scrubbers or LNG-fuelled ships will be on more familiar territory. [NA](#)

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Cabling

DNV GL develops aluminium cable type approval scheme

DNV GL has announced the release of a type approval scheme for aluminium cables and connectors and issued the first approval to Amo Specialkabel AB.

The impetus behind developing the scheme is the rising price of copper, which has become increasingly expensive over the last few decades. As the most common metal to make power cables for marine use, this has resulted in high costs for both manufacturers and shipowners.

Aluminium, therefore, represents an cost-effective alternative, with the price currently a third of that of copper. It is also significantly lighter; according to DNV GL, 60tons of copper cabling on an offshore vessel would fall to 30tons if aluminium is used, despite the need for thicker cables. This results in easier material transportation and cable installation, as well as lighter and therefore more fuel efficient vessels.

Another driving factor behind the approval scheme is what DNV GL sees as the increasingly important role of electrification in ship propulsion. The trend, says Ivar Bull, “will increase the demand and importance of finding more economical power cables.”

The type approval scheme was informed by a three year pilot installation of aluminium cables on board *Olympic Artemis* to supply power to one of its thrusters. The multi-purpose offshore vessel is owned by Bibby Offshore and managed by Olympiac, with cables supplied by Amo Specialkabel AB.

DNV GL surveyors and representatives from the cable manufacturer checked the cables with a thermographic camera, confirming perfect connection after over 11,000 operating hours. The high performance of the cables resulted in the first type approval for this equipment in the industry.

dnvgl.com

A thermographic camera checks *Olympic Artemis*' aluminium cabling



Engines

Fuelsave launches engine efficiency unit

Fuelsave GmbH, an EU-funded SME focused on fuel efficiency technologies, has launched an efficiency enhancement unit for marine engines running on MGO / MDO or HFO.

Designed to reduce fuel consumption, FS Marine+ claims a contractually guaranteed saving of ‘10% of the overall fuel costs’. The unit also helps to reduce emissions, with Fuelsave quoting figures of 10-15% for CO₂, 40% for FSN (filter smoke number), and 30-70% for NO_x, reduce engine wear and tear by up to 50%, and save approximately 33% on lube oil costs.

FS Marine+ contains a hydrogen syngas generator, which ‘combines different processes of gas and liquid water/methanol injection’ into the combustion chamber to achieve cleaner combustion, smoother engine run and exhaust smoke reduction. The unit can be retrofitted, say Fuelsave, on any vessel, helping them to achieve compliance with IMO Tiers I and II.

The efficiency and emissions-reduction potential technology has been proven via a two-and-a-half year long period of proof-of-concept testing on board a heavy-lift vessel, which has been verified through third-party analysis, and by engine maintenance companies and a university testing institute. DNV GL has approved the solution.

Fuelsave GmbH are set to benefit from €1.6million of EU Commission funding to develop FS Marine+ and encourage uptake of the unit. The company have been dubbed the ‘Top SME in Europe’ and ‘Top SME in Germany’ after being given the highest evaluation score as part of the Horizon 2020 research and innovation programme, resulting in the award of two ‘Seals of Excellence’.

fuelsave.de

Wind propulsion

Eco Flettner successfully installed on *Fehn Pollux*

Mariko GmbH, a partner in the Wind Hybrid Coaster project in tandem with MariGreen and Emden/Leer University of Applied Sciences, has successfully fitted a 90m freighter with an ‘Eco Flettner’ rotor sail at SEC GmbH & Co Shipperservices in Leer.

Starting on 1 June, the installation of the 18m high, 100 ton composite rotor on Fehn Ship Management’s *Fehn-Pollux* took a total of 18 days, during which foundations were laid, the control console integrated, the rotor lifted and installed and the crew briefed. Following a yard inclining test, on board testing, sea trials, and approval from DNV GL, the vessel has resumed standard operation. Data will now be gathered regarding the Eco



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The Eco Flettner is lifted on board *Fehn Pollux* at SEC Shipperservices



Flettner's actual performance to verify it against the positive results of simulated testing.

Operation of the Eco Flettner can either be conducted manually or automatically, with the latter the standard. The technology is able to automatically analyse wind speed and direction in order to determine rotor speed and rotation direction. The rotor is only utilised if it is determined that it will offer efficiency benefits, given that electrical energy is required to operate the rotor.

If testing is successful as expected by the project, further rotors may be installed. The installation on *Fehn Pollux* marks the first step by the Wind Hybrid Coaster project towards creating a commercially viable short-sea vessel utilising rotors for auxiliary propulsion.

The installation of the Eco Flettner marks a growing interest in the maritime industry about the potential of wind propulsion technologies, as explored in June's *The Naval Architect* ('Wind propulsion gathers momentum as installations prove successful'). A number of solutions are under development, with rotor sails – which are spun using an electric motor to capitalise on the Magnus effect, creating propulsion and therefore reducing fuel usage – the current frontrunner, with five rotors now installed on board commercial vessels.

en.marigreen.eu

Routing

MarineTraffic and NAPA sign MoU to develop voyage services

Ship tracking intelligence project MarineTraffic and maritime software house NAPA company used this year's Posidonia exhibition as the occasion to sign a Memorandum of Understanding (MoU) confirming a new collaboration to develop a number of new voyage services. According to MarineTraffic founder Dimitris Lekkas, the collaboration "will add real value to the huge volumes of data produced by both MarineTraffic and NAPA."

The services will encompass voyage planning, including port congestion forecasts, weather routing, and

post-voyage analysis reporting, which will suggest more fuel-efficient routes. Ultimately, these tools are intended to improve operational performance across the fleet.

Both of the partners are lending their particular expertise. MarineTraffic will offer ship tracking data and technical support, while NAPA will contribute its analytics, naval architecture and fuel consumption knowledge, as well as weather routing algorithms.

NAPA's director of development, Pekka Pakkanen, commented on signing the MoU: "The collaboration makes NAPA's vessel specific performance modelling and weather routing algorithms available to vast numbers of new users. These include many new stakeholders, such as short-term charterers, port agencies and other shoreside organizations, who traditionally do not have access to such data and the benefits it can bring when combined with advanced analytics."

In May, MarineTraffic signed a separate MoU with the United Nations Conference on Trade & Development (UNCTAD), in which both organisations committed to sharing their respective data to enable more accurate analysis of international shipping.

marinetraffic.com, napa.fi

System integration

ABB and Cochin Shipyard pen ro-pax system integration deal

Last month Swiss technology leader ABB and India's largest shipbuilding facility, Cochin Shipyard, signed a deal to deliver a completely integrated package of power generation, distribution, propulsion, and automation systems to two new 1,200-passenger ferries. Owned by the Andaman & Nicobar Administration and operated by Shipping Corporation of India, they will be the first vessels belonging to an Indian shipowner with system integration of this type, plying a route between the mainland and the Andaman and Nicobar Islands.

ABB will supply the switchboards, generators, transformers, power management and propulsion control systems, motors and drives, plus an alarm, monitoring and control system (IAMCS). The integration of these systems will be enabled by ABB's Ability System 800xA, which is a combination of a DCS, electrical control system and safety system.

By joining the company's Collaborative Operations network, the ferries will also be able to benefit from ABB Ability Remote Diagnostic Service for Marine, which utilises remote equipment monitoring and provides data analytics in order to enable predictive maintenance. ABB's seven Collaborative Operations Centers will further provide remote technical support.

abb.com, cochinshipyard.com

The Royal Institution of Naval Architects

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Dr Kenneth W Fisher, FRINA

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RINA-QinetiQ Maritime Innovation Award

Innovation is key to success in all sectors of the maritime industry and such innovation will stem from the development of research carried out by engineers and scientists in universities and industry, pushing forward the boundaries of design, construction and operation of marine vessels and structures

The Maritime Innovation Award seeks to encourage such innovation by recognising outstanding scientific or technological research in the areas of hydrodynamics, propulsion, structures and material which has the potential to make a significant improvement in the design, construction and operation of marine vessels and structures

The Award is made annually to either an individual or an organisation, in any country. Nominations for the Award may be made by any member of the global maritime community, and are judged by a panel of members of the Institution and QinetiQ. The award will be announced at the Institution's Annual Dinner.

Nominations are now invited for the 2018 Maritime Innovation Award. Individuals may not nominate themselves, although employees may nominate their company or organisation.



QinetiQ

Nominations may be up to 750 words and should describe the research and its potential contribution to improving the design, construction and operation of maritime vessels and structures.

Nominations may be forwarded online at www.rina.org.uk/maritimeinnovationaward

or by email to: maritimeinnovationaward@rina.org.uk

Nominations should arrive at RINA Headquarters by 31st December 2018.

Queries about the award should be forwarded to the Chief Executive at hq@rina.org.uk

25-vessel project on the Yangtze comes to a close

Yangzijiang Shipbuilding Group's successful project to build 25 10,000 TEU containerships for Seaspan was supported by an effective research programme and the desire to continuously improve the shipbuilding process

On 28 May, the 10,000 TEU container ship *CMA CGM Chennai* departed from Yangzijiang Shipbuilding Group's Taicang production area on the Yangtze River and went into operation. This launch of the vessel signifies the completion of a project by Jiangsu Yangzi Xinfu Shipbuilding (owned by Yangzijiang Shipbuilding Group) to build 25 10,000 TEU container ships for Seaspan in Canada.

The original contract for the order was formally signed on 8 June 2011. Building started in August 2012, and the first ship was delivered in early 2014. The entire project spanned nearly seven years, lending huge impetus to the Yangtze River shipbuilding industry.

The vessels, which are 337m long, 48.2m wide, have a depth of 27.2m and a draught of 15m. Each weighs 112,000dwt and can hold 10,000 standard containers.

The total construction volume of the order was nearly three million dwt. Zhang Guangqin, the former Chairman of the China National Shipbuilding Industry Association (CANSI), said at the time: "Yangzijiang Shipbuilding has successfully developed a new generation of energy-saving and environmentally friendly 10,000 TEU container ships with the most advanced level in the world. They are high-end ship products with independently-held intellectual property rights and core competitiveness, which not only set a standard for China's shipbuilding industry, but are also an important symbol for the transformation and upgrading of China's shipbuilding industry."

Economies of scale

After the outbreak of the international financial crisis in 2008, the increasingly fierce competition in the container shipping market and rising oil prices caused freight rates to fall. In tandem with



The 25-vessel, seven-year project is one of the largest in Chinese shipbuilding history

the slowdown, the International Maritime Organization (IMO) has continuously introduced more stringent environmental protection regulations. Driven by this, many liner companies worldwide have decided to exploit economies of scale to build ultra-large container ships in pursuit of lower transportation costs and greener operation. After repeated evaluation and analysis, Yangzijiang Shipbuilding decided to jointly develop the 10,000 TEU containership concept with the Marine Design and Research Institute of China (MARIC) under China State Shipbuilding Corporation (CSSC).

Yangzijiang Shipbuilding and MARIC combined the requirements of economy, energy efficiency, environmental friendliness and construction by taking the yard's 4E design concept and optimising the design of the hull structure and propulsion system. This type of 10,000 TEU vessel has a 10% increase in TEU, a 20% increase in load capacity, a 20% drop in fuel consumption and emissions, and no need for ballast water at full load, resulting in a significant improvement in operational efficiency.

Describing the difficulty of building vessels of this size, Ren Yuanlin, chairman of Yangzijiang Shipbuilding, said: "Building a 10,000 TEU container ship is technically equivalent to constructing a 108-storey building." In view of this, the company worked to improve its technical abilities. According to Yuanlin, Yangzijiang Shipbuilding spent more than two years on the technological upgrading of its hardware facilities and personnel training in order to design a high-performance vessel that took into account the draught range of all common operations plus design draughts and common operating speed ranges.

In partnership with MARIC, Yangzijiang Shipbuilding also spent the two-year period completing economic argumentation for 10,000 TEU design, plus research on hydrodynamic performance, structural design, shipbuilding system optimisation design and the application of new technologies and construction technology for large container ships. In total, the team's research project explored over 30 topics.

Regular meetings were held to track and

solve problems in the research progress and problems in implementation, leading to the reconstruction of hardware devices and process optimisation. Yangzijiang Shipbuilding also stepped up the training of relevant employees. In April 2012, professionals from classification societies were invited to hold lectures on welding practices and inspections for the construction and quality inspection personnel.

Design technologies

Following the research process, the design process began, which utilised a number of key technologies. Yangzijiang Shipbuilding evaluated the economics of different ship types through macro-scale and parameter selection; multi-scheme computational fluid dynamics (CFD) calculations and model test validation were performed to achieve profile optimisation; the finite element method was used to test anticipated loads to

analyse the strength of large-sized container ships; and the elasticity modelling was used to check the ship's fatigue strength based on bounce and vibration, and in particular that of the hull girders. Moreover, the automation level of the ship was improved via the successful design and application of a remote monitoring system; for the first time, too, the energy-saving control system of the seawater cooling pump and cabin fan was successfully applied.

In order to meet the ever-growing need for the greatest possible economy, Yangzijiang Shipbuilding carried out a further programme of design optimisation to benefit the eighth vessel onwards, taking in the vessels' draught, propeller, and hatch covers. For instance, the structural draught was increased from 15.2m to 15.5m, reducing the continuous output power from 52,290kW to 45,900kW. The speed was also reduced

to 24 knots, and twisted fins were added to further improve the propulsion efficiency and reduce fuel consumption. Further, the strength of the hatch covers was increased to increase cargo flexibility. This optimisation resulted in a decrease in fuel consumption by 8% to 20% in the 15-19knot speed range.

Throughout the seven-year period from contract to completion of the project, Yangzijiang Shipbuilding continuously improved the construction process and improved the technical level to overcome various difficulties. Improvements were seen in the time between beginning vessel construction and the opening of the dock gate, with the shortest time reduced to only 59 days. The trial cycle of only four days away from the terminal is also one of the quickest in the industry, reflecting the expertise gained in the process of the constructing the 25 vessels. **NA**

RINA - Lloyd's Register Maritime Safety Award

The safety of the seafarer and protection of the maritime environment begins with good design, followed by sound construction and efficient operation. Naval architects and engineers involved in the design, construction and operation of maritime vessels and structures can make a significant contribution to safety and the Royal Institution of Naval Architects, with the support of Lloyd's Register, wishes to recognise the achievement of engineers in improving safety at sea and the protection of the maritime environment. Such recognition serves to raise awareness and promote further improvements.

The Maritime Safety Award is presented annually to an individual, company or organisation that in the opinion of the Institution and Lloyd's Register, is judged to have made an outstanding contribution to the improvement of maritime safety or the protection of the maritime environment. Such contribution may have been made by a specific activity or over a period of time. Individuals may not nominate themselves. Nominations are now invited for the 2018 Maritime Safety Award.

Nominations of up to **750 words** should describe the nominee's contribution to:

- safety of life or protection of the marine environment, through novel or improved design, construction or operational procedures of ships or maritime structures
- the advancement of maritime safety through management, regulation, legislation or development of standards, codes of practice or guidance
- research, learned papers or publications in the field of maritime safety
- education, teaching or training in maritime safety issues



The closing date for nominations is
31st December 2018.

The Award will be announced at the Institution's
2019 Annual Dinner.

Nominations may be made by any
member of the global maritime community
and should be forwarded online at:
www.rina.org.uk/maritimesafetyaward

or by email to:
maritimesafetyaward@rina.org.uk

Queries about the Award should be
forwarded to the Chief Executive at:
hq@rina.org.uk

COMPIT's Italian job

Nick Danese reports from Castello di Pavone on this year's iteration of the Computer Applications and Information Technology in the Maritime Industries conference

Halls of noble knights, suits of armour and long swords, magnificent frescoes framing loopholes and battlements scarred from centuries past were the ideal crucible provided by the breathtaking Castello di Pavone for the alchemy that was to take place during COMPIT 2018. More than ever, the lucidity and depth of reflection directed at the all-too-practical issues and questions raised by Big Data, IoT, simulation, virtual & augmented reality and objective computational limitations will make the COMPIT 2018 proceedings essential reading for those that couldn't be there.

The widening gap between available technology, its implementation and the current users' cultures was one of the key considerations. UCL's David Andrews emphasised the need for better planning of the ship platform in order for fewer, multi-tasking crew. Herbert Koelman and Bastiaan Veelo of SARC noted how improved techniques to provide 'watertight' surface models for analysis, simulation, Virtual (VR) and Augmented Reality (AR) are facilitating their integration into the everyday workflow. Meanwhile, Ali Ebahimi et al. of Ulstein International explained how the company has made practical use of Big Data by benchmarking portions of the design space against relevant data sets, achieving 95% accuracy against the traditional full ship approach and huge time savings by bridging the Concept and Basic design phases.

Game changers

Henrique Gaspar (NTNU) presented on the creation of a "library for open and collaborative data-driven ship design" reminiscent of open-source software initiatives. This was later expanded into a 'Taxonomy for Simulation' by Fonseca et al. and taken a step further by Koch et al., who discussed the SHIPLYS project's aim of making "otherwise unaffordable resources" available to SMEs as REST-based services. Crucially, Gaspar stressed the need for data



The formidable Castello di Pavone was the setting for this year's event

"to be communicated between participating software components," a call hitherto ignored by most software houses. Enter Fischer et al. with a combined parametric-discrete strategy to estimate, track and manage costs in a multi-connected approach. There was also a parallel risk-management initiative to allow FE data visualisation and review using smartphones by Son et al. of the Korean Register.

A session dedicated to smart simulation was led off by Stefan Harries of Friendship Systems, who presented a 'web App for geometric modelling and design of propellers' made available 'via a standard web browser' (www.holiship.eu/approach). Quoting George Box's famous aphorism that "all models are wrong but some are useful," HydroComp's Don MacPherson offered a reliable, simplified simulation model for propellers. The session was capped by a powerful reminder from Denis Morais of SSI that digital twins must include IoT sensors, information about all processes from design to operation, and identification of the purpose thereof. Moreover, the paradigm shift in supply from equipment to services will require sharing of data currently "locked in silos" to ensure overall performance.

Several papers discussed digital models, twins and their use in Classification

procedures and throughout the life cycle of the ship. Christian Cabos of DNV GL discussed the "behavioural model," Jan Van Os, VP of Marine Industry, Siemens, identified Class as "the only supplier in the whole value chain" involved from start to end, while Lukas Niepert (Prostep) proposed a Class-approval process workflow, an initiative expanded on by Ulrike Moser et al. (DNV GL) via the DEX Form schema definition based on W3C standard for XML and offering the unique identification of objects (in the model) as well as preserving information about ownership.

Peter de Vos of TU Delft presented research on the use of automatic topology generation based on genetic algorithms to explore design space for energy distribution systems. Jeroen Wackers (Ecole Central de Nantes) et al. boldly bridged design space exploration, focused simulation and, to some extent, Big Data via a very interesting, always-converging, multi-fidelity approximation that uses "the sum of a low-fidelity-trained metamodel" and, perhaps crucially, the delta "between high- and low-fidelity evaluation". Auke van der Ploeg (Marin) et al. explored yet unexplained misalignments between computationally low- and high-cost hull shape optimisation.



Taking CAD from concept to reality is one of COMPIT's principal topics

Smart yards and machine learning

Gunawan et al. of Hiroshima University presented work on reducing the cost of engine rooms by optimising arrangements using a modular approach that includes layout and analogous parameters among ships of different sizes. Anne Fischer (Fraunhofer IGP) et al. introduced an innovative approach to objectively tracking building progress in the shipyard by using pictures and videos taken with common video equipment, down to tablets and smartphones, fixed and hand-held. Yong-Kuk Jeong (SNU) et al. produced further work on simulating a shipyard via a Discrete Event Simulation approach, and Jong-Hun Woo (KMOU) et al. discussed using Deep Learning algorithms to support machine learning in shipyards, written in the evergreen Python coding language. One interesting aspect of this research resides in the potential analogy with the Deep Learning approach advocated by Chess Master Gary Kasparov in his proposal to combine human creativity and machine computational power.

Rodrigo Perez Fernandez (SENER) poignantly noted that some 85% of the 2.5 quintillion bytes of data produced daily are invisible to legacy information systems, a topic dear to the writer for a long time (Danese, COMPIT 2008). This constitutes a major challenge for practical initiatives based on Big Data and empirical data such as the idea of Stein Ove Erikstad's (SAP Fedem) et al. to "use design patterns

to describe reusable solutions template" applicable to "different classes of marine systems and operation problems". This paper has the additional merits of recalling the seminal work by Erich Gamma et al. (otherwise known as the 'Gang of Four'), pointing out that design patterns also reveal differences and finally recognising that digital twins should be seen as "opportunity makers". Equally noteworthy notice is Zou Guangrong's work on combining Big Data and Artificial Intelligence, analogue to Deep Thinking, and identifying that "future twins will be digital by design" as opposed to twins identical to their physical counterparts.

Training and navigation

Volker Bertram (DNV GL) et al. dissected the definition of VR and provided a comprehensive survey of currently available VR options for maritime training, their pros and cons, applicability and relative cost, as well as a sobering review of the outcome of a few recent development projects. One more successful initiative was discussed by Nikolaj Meluzov (TUHH) dealing with "a toolkit for AR-based service instruction modules," including CAD models, the fundamental what/where/when/how questions and, for the perhaps the first time, feedback. On a more promising note, Guillaume Jacquenot (Sirehna) reported constructive results in the application of VR to CFD, effectively plunging the viewer into a flow field, the aim being to allow the study of 3D phenomena 'from the inside'.

The seldom heard of concept of just-in-time operation, changes to speed and course, and the importance of unloaded voyages were related to GHG emissions by Toshiyuki Kano, (National Maritime Research Institute, Tokyo), who identified the propulsion plant's condition as a common culprit in efficiency losses. Hideo Orihara et al. (JMUC) expanded on this by calling for more ships optimised to the weather conditions of their expected principal operational theatre and, conversely, to use real-time weather data (local and to destination) to continually fine-tune planned routes. Waiting for weather windows is also advocated and could lead to fuel savings of up to 30%. Taking the collaborative approach a stage further, Andrea Orlandi (of the Tuscany-based LaMMA Consortium) et al. called for 'nowcasting': ships transmitting real-time weather and related data to each other and to a communal weather mapping and predicting base station. Waiting for favourable weather windows and improved routing are estimated to account for up to 16% reduction in wave resistance and fuel savings of 10%.

Many dramatic collisions involving high-profile ships have been reported in recent months, but far more and far worse incidents never make the news. Stephan Procee (Maritiem Instituut Willem Barentsz) discussed an ecological interface that uses AR with the aim of improving the ability to distinguish potentially dangerous targets threatening the Ship's Domain (Protected Zone) from the rest. A creative line was

taken by Marius Brinkmann (University of Oldenburg) in combining a real vessel and its real-time navigation condition with a simulated environment, for risk-free testing of collision avoidance systems. For an idea clearly oriented towards autonomous ships, the very recent high-accuracy positioning satellite network Galileo is used by Agnes Schubert (University of Applied Science, Wismar) et al. to provide a Navigation Assistance System offering dynamic support to situation assessment, a task currently carried out by bridge officers.

Unmanned ships and AI

Legislative and insurance bodies have now entered the arena of unmanned ships, driving the distinction between unmanned and autonomous vessels, floating and submerged. Mikael Lind (RISE Viktoria, Gothenburg) et al. highlighted the exponentially increasing congestion of routes and, critically, port areas – a recent statistic puts the number of sea-going cargo ships at 100,000 – and a new Sea Traffic

Management system defined on modern technology is being called for by Swedish authorities. Jukka Merenluoto (DIMECC, Finland) also noted “the development of new technology opens new opportunities, which need social change to be accepted and taken into use”. There might be grounds to argue the presented view that “transition from the conventional vessels will take time as the lifespan of the existing fleets are long” which would however lend more substance to their call for the ‘One Sea’ initiative (see March 2018’s *The Naval Architect*). Also very future looking, Kohei Matsuo (NMRI, Tokyo) reviewed ‘Technology Mega-Trends that will Change Shipbuilding’ concluding, somewhat surprisingly, that “ultimate customisation and shift to service business” tops the list.

In ‘Demystifying Artificial Intelligence for Maritime Applications’, Bertram reviewed what AI currently means, while Christos Gkerekos (University of Strathclyde) presented data driven fuel consumption modelling aimed at reducing the “25% of the vessel’s overall running costs” it represents.

Jing Xie (DNV GL) presented research aimed at identifying structural cracks by applying neural networks to drone-taken photographs during surveys, while Henrik Holm (RISE Viktoria) highlighted the need to decode massive amounts of AIS data in faster ways to make it more relevant to its consumers.

Among other highlights, the DNV GL COMPIT Award 2018 was bestowed upon Stefan Harries in recognition of his many achievements throughout his ongoing distinguished career.

You can find all the full papers presented at this year’s event at: http://data.hiper-conf.info/compit2018_pavone.pdf

About the author

Nick Danese is the founder of Nick Danese Applied Research (NDAR), a consultancy specialising in engineering and system integration of products such as ShipConstructor, MAESTRO, ShipWeight, GHS and Navisworks. He regularly presents at conferences and seminars on aspects of ship design and construction. **NA**

The Royal Institution of Naval Architects

International Conference: WARSHIP 2018: Procurement of Future Surface Vessels

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Open Registration



Modern navies are increasingly having to manage the trade-off between capability and cost. Versatility, flexibility, and affordability are key criteria which designers need to balance as warships become an exportable commodity, where market value may be just as important as the strategic value of any newly built vessel. Many nations are designing vessels with exportability in mind, this can mean that the Navy needs to accept some compromises to achieve this. On the other hand other nations are looking to build up their sovereign capability or to create jobs in country for national prosperity. In this scenario the nation must select a partner who can provide some degree of technology transfer and the key driver may not necessarily be the ships capability.

All of this is against the backdrop of rapidly advancing technologies including unmanned and autonomous systems, a changing threat environment and an insecure world; these factors require ever more adaptable ships that can fulfil a number of different roles and save money through life. Modularity may be one way to address this adaptability, however this approach has its compromises and there are other design considerations that must be in place to make a platform truly adaptable.

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LIEBHERR

ClassNK's fifth generation PrimeShip-HULL adds new sharing dimension

Four years after becoming the first class society to develop and release software to do the intensive calculations called for by IACS' Common Structural Rules (CSR), ClassNK is aiming to stay ahead

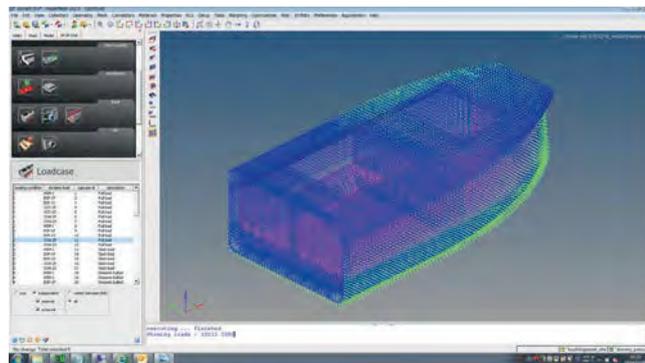
Adopted by International Association of Classification Societies (IACS) in 2013, the Common Structural Rules (CSRs) were designed to enhance ship safety and reliability by requiring a more comprehensive structural analysis at the design stage. The new rules encompassed the need for FEM analyses covering the entire range of cargo hold structures, as well as new formulae for buckling, fatigue, and residual strength criteria.

The CSRs represented a self-evident step forward for the safety of bulk carriers and oil tankers, but they also brought practical challenges for shipyards and vessel designers as the calculations needed to perform these analyses and satisfy the requirements are both complicated and time-consuming. They add considerably to overall vessel design time. Indeed, before their introduction, there were fears that the rules would impose such an impossible burden that yards would be unable to cope.

ClassNK created PrimeShip-HULL expressly to alleviate this burden. The solution is now used by around 90 shipbuilding and design companies, located mainly in Japan, South Korea, China and other countries in East Asia – reflecting where most of the world's ships are now built. In fact, with more than 600 licenses in use, most shipyards constructing the ships subject to the CSR now utilise ClassNK's software.

Earlier this year ClassNK released the fifth version of PrimeShip-HULL. As well as absorbing IACS' latest round of amendments to CSR, the update includes several refinements to existing functions and introduces some completely new ones aimed at sustaining the software's uptake.

In addition to user interface tweaks aimed at streamlined workflow, the report generator in PrimeShip HULL's prescriptive calculation software now operates independently. This allows users



PrimeShip's HULL interface has been tweaked for a more streamlined user experience

to continue editing cross-section data or other tasks whilst a report is generated in the background.

The ability to transfer data between the CAD – and other design tools used by naval architects – and PrimeShip-HULL quickly and efficiently has been key to the software's success. In the latest round of improvements, the data linkage function for importing body plan data from 2D CAD software has been further enhanced making it possible to create sectional data from the body all at once, eliminating the need for repetitious data conversion.

PrimeShip-HULL is tightly integrated with NAPA Steel, the program most widely used by the world's shipyards. For instance, in the case of oil tankers, data from 3D structures such as transverse webs, bulkheads and other non-longitudinal members can be effortlessly transferred between the two applications. This is particularly helpful when conducting structural evaluations in the initial design phase.

The direct strength assessment software now includes a parameter check and update function which can detect model-dependent parameters and update them automatically. This saves time by preventing parameter setting errors that would otherwise require the assessment to be redone. The yield assessment calculator has become more

user-friendly and the buckling assessment calculator has been optimised to shorten the calculation times.

Overall, the enhancements and new functions will further reduce necessary man hours and shorten design lead times. Some yards have reported a reduction in the man hours spent on structural evaluation for prescriptive requirements and for direct strength requirements through Finite Element Analysis (FEA), although results depend on vessel type, structure, and coarseness of the original CAD data.

In addition, ClassNK offers a version of PrimeShip-HULL for container ships, even though the vessel type is not subject to IACS CSRs. Its availability demonstrates that the rule calculation system's ability to evaluate strength requirements such as hull girder strength, local strength, buckling strength, ultimate strength and fatigue strength has an inherent value for designers and shipbuilders. The direct strength calculation is capable of conducting FEA and can be used to perform various yield, buckling and torsional strength analyses, for example. The system is also capable of proposing reinforcement plans using sensitivity analysis, with data linking into NAPA Steel.

ClassNK continues to offer PrimeShip-HULL to shipyards and designers free of charge. **NA**

Rethinking CSR design waves

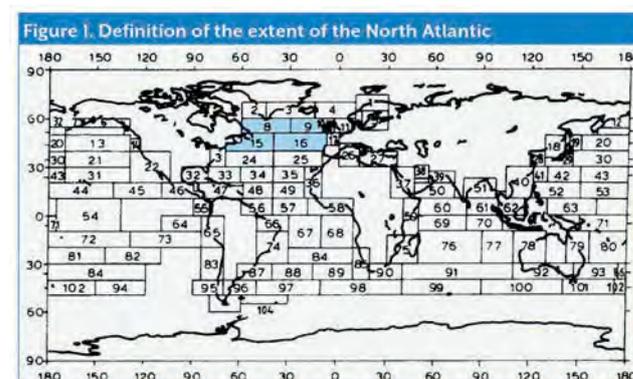
Bringing IACS' Common Structural Rules into line with IMO's Goal-Based Standards has resulted in a non-equal heading probability model for calculating the probable stresses on bulkers and oil tankers

The International Association of Classification Societies (IACS) first published its Common Structural Rules for bulk carriers (CSR-BC) and Common Structural Rules for oil tankers (CSR-OT) in 2005, formally adopting them in 2006. Because the two ship types broadly shared many characteristics – e.g. loads, ship motions and accelerations and hull girder strengths – there were obvious benefits to harmonising them.

Philippe Baumans, who is currently halfway through a three-year tenure as the Chair of IACS' Hull Panel, has long been involved with the development of CSR. He explains: "We didn't want to reinvent the wheel and so looked to harmonise areas of commonality. We aimed to accommodate small differences and when it was really specific – such as the different bulkheads for dry and liquid cargoes – these would be covered in separate parts."

In part, the CSR BC&OT adopted in 2013 anticipated IMO's introduction of the overarching Goal-Based Standards (GBS) framework for ship design and construction, and in 2016 this compliance of CSR with GBS was confirmed by the IMO's Maritime Safety Committee at MSC96. However, this now means that all bulkers and tankers over 150m length constructed after 1 July 2016 now also need to comply with the GBS requirements in SOLAS, any changes to the CSR affecting GBS compliance must be verified by the IMO.

IMO's initial auditing process raised some non-conformities and observations which IACS were obliged to address; among these were some of the assumptions underlying the probability distribution model for a ship's response to waves. The technical background for these is extensively detailed on the IACS website and the corrective actions in relation to the non-conformities were completed in the first half of 2017. As a facet of this work, the IACS Hull Panel decided to



Under IACS CSR, a vessel is expected to be able to withstand 25 years of operating in 'North Atlantic' conditions - the blue highlighted squares on the grid

form a dedicated project team to take a fresh look at the wave loads definitions that form the basis for these models.

Probability model

Equivalent Design Waves (EDW) were devised as a practical means of modelling the waves used in computing the stresses a vessel will be subjected to across a 25-year lifespan operating in the North Atlantic, which is considered to reflect the appropriate operating conditions in designing these vessels. The North Atlantic is represented by a two parameter Pierson Moskowitz wave spectrum $S(\omega)=fct(H_s, T_z, \omega)$, where ω is the angular wave-frequency.

While IMO's GBS requirements aren't specific in relation to what constitutes 'North Atlantic', the 2000-published IACS Recommendation 34 for Standard Wave Data stipulates a four-zone region (see Figure 1), which has assumed de facto status. The data recorded for this area by BMT's Global Wave Statistics had shown that regular waves fell within a narrow-band spectrum and this data is typically recorded in a matrix which discretises the wave height (H_s) and the mean zero up-crossing wave period (T_z). From this it has been possible to calculate the long-term probabilities of the ship responses.

However, this probability model was based on the assumption that waves were of equal heading probability and could come from any direction, something the IMO's GBS auditors didn't agree with. Baumans explains: "They said that it was more probable that the waves come from certain directions, but the difficulty is that a non-equal heading probability model doesn't exist."

The solution was to consider the situations in which a ship's master might be compelled to adjust course in response to the undesirable effect of waves. It was determined that a change in direction most frequently occurred when one of three conditions were met:

1. When likely to exceed a given roll angle.
2. When the freeboard at the forward part of the ship became too small.
3. When the propeller is no longer fully immersed.

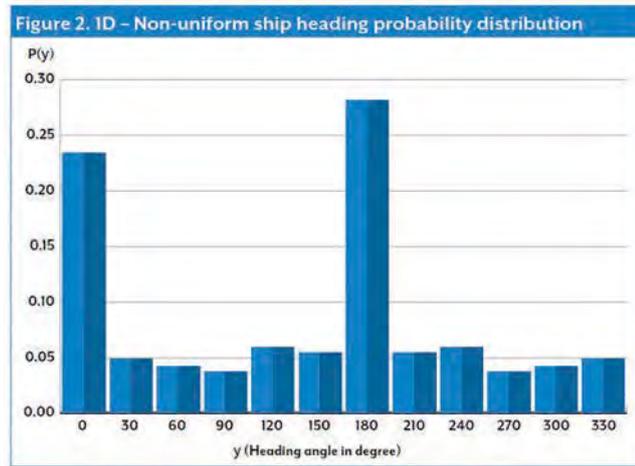
Baumans explains: "We created a probability model for 3D situations for 22 bulk carriers and 27 oil tankers of different sizes, to calculate what happened under those conditions. As this was quite burdensome it was determined we could achieve with good accuracy the same results with a 1D probability model."

The results (see Figure 2) indicated that some ship headings, notably a head or

following sea, had a far higher probability of occurrence than others. But what was really needed was how this impacted on the design loads and scantling compared to the earlier uniform model for CSR.

“When we calculated with this new EDW we found that some factors increase, while other factors decrease. There was an increase of between 4% and 4.5% for the vertical shear force, vertical wave-bending moments amidships, and surge and pitch accelerations in head or following sea conditions. In beam sea conditions, there is less pressure at the waterline amidships and a decrease in heave and roll accelerations of 4% to 4.5%, while with transverse or oblique sea conditions there are less horizontal wave bending moments (2.5-3.0%).

“So we decided that where there was an increase in wave parameters we would introduce a coefficient of 1.05 in the CSR



IACS' probability modelling indicated that ship headings were predominantly into head or following (180°) seas

for amplifying the long-term values of the pressure from accelerations and hull girder stresses. When there was a decrease no corrections were made for precautionary reasons, but we applied this coefficient in

head sea and following sea cases, on the vertical wave-bending moment, on the shear force and the accelerations. So this coefficient was introduced into the rules on 1 January 2018.” [NA](#)

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Making cyber security part of the newbuilding process

An essential component of today's connected vessels, cyber security is most effective when it is built in. Through discussion, testing and verification, DNV GL is making it a key part of design and construction

Maritime cyber security is primarily thought of as one of the day-to-day responsibilities of the shipowner and their crew. Much like correctly functioning equipment, cyber security is an essential part of vessel operation, which will quickly be compromised if either of these fails in some way.

The focus on the cyber security of operational vessels is understandable given that cyber-attacks whilst at sea can have serious consequences for the vessel, the environment, the crew and the shipowner. As such, cyber security guidance typically promotes best practice with regard to seafarer cyber awareness (sometimes referred to as 'the human element'), training, and updating software to stay protected in an ever-changing threat landscape

However, certain quarters of the industry are looking to take a step backwards by thinking about cyber security as part of newbuilding. The idea suggests that cyber security should be considered as much a part of a vessel's design as its engine or its hull form – a fundamental component to be fully integrated, tested and verified as part of the newbuild process. The logic behind promoting cyber security in newbuildings is that a vessel can be designed to be 'inherently secure', with every system assessed and optimised before commissioning.

The most significant project so far to develop this idea is IACS' plan to release 12 recommended practices relating to cyber security and resilience in newbuildings, which the Association will present to the IMO in December at MSC 100. Designed to complement the operational focus of BIMCO's 'The Guidelines on Cyber Security Onboard Ships' and the IMO's 'Guidelines on maritime cyber risk management' adopted in 2017, the recommendations



Patrick Rossi speaking on cyber security at Posidonia

will be released sequentially and focus on identifying and protecting newbuildings' myriad "attack surfaces," as described by IACS Chairman Knut Ørbeck-Nilssen. As ships become increasingly digitalised and connected both to the shore and other vessels, protecting these "surfaces" from the outset has become essential.

New notations

DNV GL, of which Ørbeck-Nilssen is CEO, is another frontrunner in developing cyber security services for newbuildings. At the Posidonia exhibition in June, the class society announced that a set of cyber security notations – Cyber Secure Basic, Cyber Secure Advanced, and Cyber Secure (+) – would be released on the 1st July. 'Basic' is intended for ships in operation, '(+)' for additional systems beyond power generation, navigation, propulsion and steering, and 'Advanced' specifically for newbuildings, with requirements for owners, yards, and manufacturers.

To understand the role of these stakeholders in installing cyber security in newbuildings, *The Naval Architect* spoke with Patrick Rossi, DNV GL's principal cyber security service manager in their maritime division. Rossi leads a team

which outlines vessels' cyber security requirements, verifies the systems put in place to meet them, and monitors them. These processes make up what Rossi calls 'cyber risk life cycle management,' which has its foundation at the newbuilding stage.

For Rossi, it is essential in newbuilding projects for all stakeholders to discuss, understand and agree on the vessel's particular cyber requirements. As he notes: "If you pick a yard and look at a vessel that they've already built hundreds of before, you're basically copying and pasting the design, the software, and possibly using the same vendors and so forth. You've already worked out all the problems. But when you're [building] new, complex vessels, you can encounter a new yard, new teams and new cyber functionalities".

The combination of unique design requirements, new stakeholders who may have never worked together before, and the presence of multiple vendors and subcontractors sets a learning curve for the newbuilding project, so discussions on cyber security requirements from the get-go help to create mutual understanding. Rossi says: "DNV GL put people in a room together and we start drawing up a threat picture so everybody

understands. You have the owner/operator, the vendors, the yard around the same table, and they exchange their view of the threats. This is very helpful for our industry, as typically these people do not all sit down together to discuss these things.”

Besides helping to create a mutually-agreed cyber security plan moving forwards, Rossi suggests that these discussions also help streamline relationships between different suppliers: “If I’m making a system and you’re making a system, and our two systems need to talk, it’s in my interest that your system doesn’t get infected.” This, he explains, helps to expedite the long and often bureaucratic contracting process that takes place in every newbuilding project: “The fact that they all have a common enemy helps transgress layers of contracts.”

Defence in depth

Although every newbuilding will have different cyber requirements and software systems, one common principle that such discussions attempt to uphold is ‘defence in depth’. Rossi explains that this means multiple layers of protection intended to put off hackers and cyber criminals; while they may be able to compromise

one or even multiple layers, the effort required to completely break through acts as a deterrent. These layers can either be digital – for example a firewall or two-step verification – or physical, such as a secure lock on a cabling cabinet.

A key enabler of ‘defence in depth’ is the deliberate segregation of different networks on board the vessel, so gaining access to one does not mean access to all. This is especially important for so-called ‘safety-critical systems’, such as the fire detection system, which must be operational even if another system or network is compromised. Segregation can be achieved by making sure that networks do not interact unnecessarily, isolating segments, restricting traffic and physically ensuring wires are not crossing at any point.

Also important is what Rossi calls a “hardening of systems”. This involves locking down workstations by identifying easy ways in, such as admin rights that don’t belong, or default manufacturer passwords and credentials for equipment (many of which can be found in a quick online search) and stamping them out. The use of obsolete software such as Windows XP is also discouraged, as it is vulnerable and rarely patched. It is surprisingly common in the maritime industry for

equipment and systems manufacturers to use outdated operating systems, offering a boon to cyber criminals.

In order to verify the numerous barriers agreed upon and set up at the newbuilding stage, DNV GL carry out a programme of penetration testing using certified ethical hackers like Rossi himself. This testing, which replicates real, malicious attacks, attempts to identify weaknesses in each barrier and fix them to solidify the layers of redundancy and resilience before the vessel leaves the yard.

As Rossi points out, thinking like a hacker while designing a system is a somewhat contradictory process: “You’re building something and trying to break it at the same time.” In order to achieve improvements, it must first be imagined how systems can be compromised and made to fail, and at a later stage undergo hacking to see if the barriers are holding. This isn’t unique to cyber security; known as FMECA (failure mode, effects, and criticality analysis) it is a common procedure in system and product design.

Shipyards and cyber security

Rossi notes that shipyards have not generally taken an in-depth role in the cyber security of vessels, seeing it as outside of their remit: “The yards normally translate what the owner is asking for, and add their experience. They typically are not the ones that manufacture software, and cyber security is an offspring of this software. It is seen as something that is done by the vendors, and so the yard says that’s not my scope – I make sure the system does what it’s supposed to do.” In other words, whilst the yard will confirm that systems are up and running, they will not look at how each system relates to another and the impacts this might have on cyber security.

However, DNV GL use the analogy of purchasing a car with a fault to argue why yards might take a greater role in cyber security during newbuilding projects. As Rossi explains, if you bought a car from a dealer and noticed the CD player wasn’t working shortly after driving away, the dealer would not tell you that it is Sony’s problem; they understand that they are the system integrator, and it is therefore ultimately their responsibility.



Onboard surveys and testing help to clarify holes in a vessel’s cyber security before it enters service

In the same way, yards have a responsibility to optimise, or at least understand, a vessel's RAMS (Reliability, Availability, Maintainability and Safety/Security) provisions. This is especially pertinent given that IT and OT (operational technology) are being brought ever closer by Big Data and the Internet of Things, which enable practices such as the remote monitoring of engines and propulsion systems. Machinery and equipment, where yards' expertise typically applies, are now being implicated in a vessel's cyber security; as such, they must consider both the engineering and digital sides of vessel design and construction to ensure newbuildings are optimised and safe.

The active participation of a yard in building-in effective cyber security is also important given that cyber criminals often seek out vulnerabilities early on, in order to attack later. Rossi

says: "[A hacker] is either planting a back door during newbuilding, or [the yard] could be designing a ship with an open door that will allow someone to plant a back door during operation." For DNV GL, the purpose of their testing and verification is to find these doors and secure or remove them before they can be exploited, requiring the yard's co-operation as the system integrator. Ensuring that the yard's own systems are secure, too, is essential; the wide range of third parties and subcontractors working on each project means that malware or ransomware can easily be introduced by a corrupted device.

Working together

By involving all parties in cyber security from the beginning in newbuilding projects, DNV GL hope to certify a new generation of safer vessels for which cyber security is an essential part of

their design and construction. With the voluntary Cyber Security Advanced notation, shipowners can demonstrate a commitment to protecting their vessels' systems – and by extension their clients' data and cargo – which is likely to have a positive business impact in an increasingly security-conscious age. Pre-release, DNV GL have quoted interest from over 10 vessels, and a high number of enquiries.

Although cyber risk life cycle management by no means ends at commissioning, instilling robust systems at newbuilding prioritises prevention over cure. Owing to its reliance on outdated systems and lack of cyber awareness, the maritime industry is a soft target in a world where many industries have learned hard lessons. However, by going back to drawing board, effective cyber security can be designed-in to prove that maritime is not to be taken advantage of. **NA**

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The bigger they are, the greater the risk

With containerships set to surpass 22,000 TEU, concerns are growing over whether size might impact safety. *The Naval Architect* examines the risks, and considers the insurer's perspective



The year-on-year growth of containerships has not necessarily been accompanied by comparable developments in safety equipment and training

On 12 June, China State Shipbuilding Corporation (CSSC) handed over COSCO *Shipping Universe* to its new owner, China Ocean Shipping Company (COSCO). Muscling in at 400m long and 58.6m wide, it has a deadweight of 198,000 tons – 6500dwt heavier than the 2017-built *OOCL Hong Kong*, the world's largest containership. When it comes to TEU, however, the latter wins out, accommodating an astonishing 21,413 TEU to *Universe's* 21,237 TEU.

Truly the goliaths of cargo shipping, vessels in the 20,000 TEU+ category currently represent only a small part of the segment. Nevertheless, the demand for such giants appears to be on the rise. *OOCL Hong Kong* is one of a series of six, and five sister ships to *COSCO Shipping Universe* are due for delivery next year, followed by a set of four 22,000 TEU+ vessels. French major CMA CGM has nine 22,000 TEU vessels on order, which notably will be the first of this size powered by LNG. Other lines with 20,000 TEU+ vessels include Evergreen, MOL and Maersk, with the Danish shipper owning a series of ten 20,568 TEU vessels led by 2017's *Madrid Maersk*.

The year-on-year size increases suggest that these ultra-large container ships (ULCS) are only set to keep on growing. With ships on order that will surpass the much-heralded 22,000 TEU barrier, figures of 24,000 are already being quoted for the next generation.

Such vessels are certain to have a significant impact on the containership market. By exploiting economies of scale to a huge extent, they are theoretically the most efficient in terms of being able to transport the greatest number of containers at the lowest relative fuel cost, meaning attractive rates for shippers.

However, the standout size of ULCS also has a negative impact on two major areas of ship operation, one of them logistics. With ULCS falling into the post-neopanamax category, routing is less flexible, with fuel savings potentially cancelled out by the necessity of making longer journeys. Furthermore, only a small number of ports are able to accommodate – and indeed load and unload – such vessels, contributing to their restricted operation. Another concern is the lack of suitably qualified crew able to handle ULCS, given that they require a substantial increase in

manpower. This is particularly pressing for nonstandard vessels such as the aforementioned LNG-fuelled CMA CGM ships.

The second, and more important area, is that of safety. Unfortunately, it has taken a number of incidents to raise the question of whether increasingly large vessels are as safe as their smaller counterparts, the most significant being the recent fire on Maersk H-class vessel *Maersk Honam* which claimed the lives of five seafarers (see April's *The Naval Architect*). Although not in the 20,000 TEU+ range, the vessel is nonetheless sizable, with a maximum TEU of 15,226, making it the largest containership to suffer a fatal incident in recent years. Particularly notable is the fact that the vessel was only launched in May 2017, and is therefore equipped with up-to-date safety systems.

An investigation into the incident is ongoing. However, the fire is known to have started in the forward hold, spreading aft and growing in intensity. A number of vessels were required to bring the fire under control (although it was still burning after three weeks) after which *Maersk Honam* was towed to the Port of Jebel Ali.

There is no suggestion at present that



Fires on board container vessels can be very difficult, sometimes impossible, for crew to tackle

Maersk Honam was deficient in any of its safety provisions, or that its size exacerbated the impact of the fire. However, the incident is a stepping stone towards discussing the safety issues faced by containerships – and whether ULCS might have their own unique problems.

To explore these issues, *The Naval Architect* spoke with Allianz Global Corporate and Speciality’s global head of marine risk consulting, Captain Rahul Khanna. According to Capt. Khanna, containerships of any size have a number of specific risks associated with them. For instance, the large windage area of containerships means that navigation, particularly in bad conditions, can become difficult, leading to potential safety issues.

Far more common are risks associated with cargo, with loss of containers a well-known problem; between 2015 and 2017, the World Shipping Council estimated average annual losses of 1,390 containers. Damage to containers and cargo due to stack collapse caused by mis-declared weight is also a significant risk; Capt. Khanna notes that annual supply chain losses related to packing failures have been estimated to cost around US\$500 million.

Due to the sheer increase in the number of containers, ULCS face a greater risk of both losing and damaging containers. However, a more serious risk is that of incorrectly declared – and therefore potentially hazardous – cargo, which can lead to fires that are incredibly hard to contain if crew do not know what caused the blaze.

Fire is a risk attached to almost all maritime operations, but a recent string of

incidents on board containerships in particular has put the segment under the spotlight. Whilst containerships of all sizes face similar risks as to the causes of fire, Capt. Khanna notes that ULCS have a greater risk when it comes to containing blazes: “It seems it is no longer always possible for the crew on board to fight or contain large fires. Fire-fighting capabilities on board have not necessarily kept pace with increasing vessel sizes. Insurers such as Allianz and the International Union of Marine Insurance have previously warned of safety concerns in this area and are promoting improved ship design and fire-fighting equipment.”

The notion that ship design itself might be contributing to the problem is particularly worrying, although all vessels have a design that is theoretically safe from a regulatory perspective. On a practical level, however, it is clear that fire-fighting equipment, and crew fire-fighting training, is no match for the sheer scale and intensity that fires can grow to on larger vessels, as on *Maersk Honam*, which required the assistance of three vessels. 2017’s July/August issue of *The Naval Architect* saw ABS’s Matthew Tremblay consider the challenges of fire-fighting on large containerships, noting the extra demands placed on fire water supply systems and physical exertion required by seafarers.

In the event that fires are not contained, ULCS present problems for salvage operations, Captain Khanna suggests: “Due to the sheer size of these vessels, handling and managing a casualty involving such ships becomes exponentially difficult. Salvage and wreck removal can be a very complex

problem to solve.” Remarking that salvaging ULCS “is indeed a specialised job,” Capt. Khanna notes that “the cost of salvage and wreck removal also increases exponentially,” meaning higher costs for insurers and therefore shipowners.

In the event of a successful salvaging operation, the next problem encountered is a lack of suitable ports of refuge, with only a small number of ports able to accommodate such vessels. This can cause delays in shippers recovering their cargo, the care of (possibly injured) crew members, and investigations into the causes of the incident.

This catalogue of risks might give the impression that shipowners are playing with fire in choosing to commission ULCS. However, it is important to note that no vessels greater in size than *Maersk Honam* have yet reported a fatal accident. With all containerships facing a set of risks, it would be wrong to accuse ULCS of being particularly dangerous.

Despite this, the uncertainty of how effectively crew, coastguards, salvors, and ports could respond to an incident on a vessel of 20,000 TEU or over is certainly a cause for concern, and one that will only be allayed when such an incident occurs.

Questioned over whether insurers might end up seeing the risks of such vessels as too great, Capt. Khanna framed the debate slightly differently: “Evolution of ships has been a feature of the shipping industry since the beginning and is driven by innovation, economic necessity and insurance. Although these vessels can represent a heightened risk, insurance needs to provide support, as it always has. What we would like to see is that these risks are properly managed and risk mitigation measures put in place to commensurate to the increase of risk profile.”

Who will take the lead on investigating and managing these risks, and how, is an unanswered question. Nonetheless, the responsibility on the industry as a whole to ensure SOLAS suggests that all sides have a part to play in the discussion. What is certain is that such discussions ought to take place as a matter of urgency, as consistently larger vessels leave their yards and enter service with each passing month. **NA**

ABB's turbocharging solution is fit for purpose

With the promise of significant efficiency gains and reduced maintenance, the FiTS2 system has been designed with the realities of modern shipping very much in mind

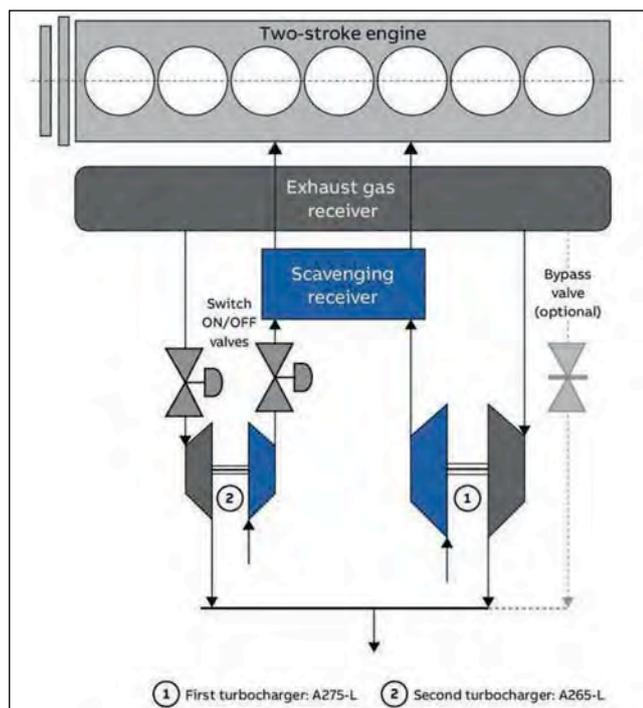
Nearly 100 years have passed since exhaust gas turbocharging technology was first incorporated into large marine engines. Those first installations, onboard the German passenger ships *Hansestadt Danzig* and *Preussen*, were based on a patented design by the Swiss engineer Alfred Büchi and built under his supervision by Swiss company Brown Boveri & Cie, the company commonly known today as ABB.

The basic principle, forced induction of the engine exhaust gas into the combustion chamber, is essentially unchanged. For diesel cycle engines turbocharging can increase the output by 300%, meaning that a two-stroke engine would need to be quadruple the size to achieve the same results. Simply put, larger vessels would look very different without turbocharging technology.

During shipping's boom years, when bunker prices were less prohibitive and it was more common for engines to operate at closer to full load, turbochargers could be optimised to deliver the greatest efficiency at a high pressure rating. But when fuel prices began to rise steeply to over US\$500 per ton circa 2010, coupled with the decline in trade, slow steaming, and in some cases ultra-slow steaming, became an economic necessity for many shipowners. It was not uncommon for a container ship to be running at as little as 10-15% of its engine load.

Even after bunker prices dropped to a historical low of US\$300 per ton, increased regulation such as IMO's Energy Efficiency Design Index meant the emphasis remained on engines being run on part load, with an average derating of around 20%. For better or worse, the days when a container ship might travel at speed upwards of 25knots are very much a thing of the past.

But – unless one of the turbochargers is taken out of operation – this means that the auxiliary electrical blowers, ostensibly meant for the starting and stopping of the engine,



By switching between different sized turbochargers, the FiTS2 system optimises scavenger air pressure

may be running almost continuously, which not only consumes additional fuel to power the auxiliary generators but increases the risk of technical problems and breakdowns. Moreover, the 2020 sulphur cap raises additional challenges. With low-sulphur fuels and gas engines temperature plays an important role in maintaining a stable rate of combustion, while scrubbers create generate back pressure that holds back exhaust gas.

These problems can be overcome by increased efficiency in the turbocharging system, according to ABB's Arie Smits, senior general manager for the Swedish-Swiss company's global turbocharging sales. At December's Marintec trade show in China, ABB launched its 'Flexible integrated Turbocharging System for 2-Stroke Engines' (FiTS2), a technology developed in collaboration with two-stroke engine makers Winterhur Gas & Diesel (WinGD). The system is

comprised of two or more sequential turbochargers of different specifications working together to complement each other's air delivery at different engine loads, controlled by tuning software and combined with flow optimised valves. The system ensures energy efficiency by operating just a single turbocharger for lower loads and switching to two (or even three, in the case of larger vessels) at higher loads (typically upwards of 50-60%).

Explaining the thinking behind the new system, Smits explains: "Historically we've developed turbochargers where we had the highest efficiency at the highest pressure ratio. For lower loads you need efficiency at the lower part, compressor wheels [in the turbocharger] with a high volume flow that deliver high efficiency at part load. That has led to a number of advantages, because by downsizing we could use a smaller turbocharger, which can reduce costs.

“But with the FiTS2 there are three possibilities: typically we might use a smaller and a bigger turbocharger, and then switch the smaller one off at high load. The remaining turbocharger would then only run at part or low load and because it gets all the gases it would run at a somewhat higher speed, which brings a high pressure ratio.”

By using wide compressor maps, switching between the turbochargers can be achieved without surging and instability. Meanwhile, on the basis of this higher pressure ratio the engine designer adjusts the tuning and timing of the valves and injection to increase combustion pressure and lower fuel consumption. An integrated engine control system then determines when the valves should be operated.

What's more, because there is the option to switch off turbochargers, the increased pressure ratio means there is less demand on the auxiliary electrical fans, which are now only required at a 25% load, allowing for further savings.



The turbocharging system includes specially designed pneumatic cut-off valves

While sequential turbocharging is nothing new in itself, having been in existence for nearly 30 years, Smits says it's the improved stability of valves, flexibility of engines and adjustable fuel pressure which makes the FiTS2 possible. “It's a clever use of known technology with optimum components and close co-operation with the engine designer. We're moving away now from turbochargers to integrated turbocharging systems.”

Smits admits that initial testing of the technology on a full-scale engine in Japan was a somewhat protracted process, but the project is now making good progress. ABB and WinGD are currently in the process of fitting a pilot system to a Chinese-built bulk carrier which is scheduled to launch sometime in 2019. Smits was coy when it came to disclosing the ship's owner but did reveal they are not themselves Chinese.

The initial capex for a FiTS2 setup is likely to be around US\$60,000, with perhaps some additional costs for equipment such as an extra oil pump for the crosshead lubrication, or a damper if one is required. However, payback is estimated by ABB to be achieved in less than two years from the resulting savings with overall fuel savings over 10 years being in excess of US\$1 million for a container ship. To assist owners in determining the potential benefits of FiTS2 over conventional turbocharging, ABB has developed an online fuel calculator (<http://abbfits2.oakwoodagency.com>) **NA**

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A power correction method for speed-power sea trials data analysis

Speed-power performance is one of the most important aspects of a shipbuilding contract, as well as part of EEDI. Dr Bogdan Ganea, and Dr Kieran Dodworth, of Brookes Bell Safety at Sea, propose a method for power correction that avoids calculating propeller overload factors

The direct power method was part of the British Ship Research Association's (BSRA) method [1] which enjoyed a long period as the predominant method of power correction. However, the BSRA version does not account for the propeller overload during sea trials, which is an obvious drawback to this approach. The propeller overloading affects the propulsive coefficients (wake fraction, thrust deduction factor, relative rotative efficiency) and the propeller open water efficiency. The combination of these parameters defines the quasi-propulsive efficiency which is a synthetic indicator of the quality of the propulsion design. In effect, the BSRA method neglects the variation of the quasi-propulsive efficiency with propeller overload.

Another well-established and widely used method was the Taniguchi-Tamura method, [2], implemented in the ISO standard 15016, version 2002 and the International Towing Tank Conference (ITTC – see <http://itcc.info>) guidelines, version 2005. This method uses the propeller open water characteristics to calculate the propeller open water efficiency variation. At its 62nd session in 2011, IMO's Marine Environment Protection Committee (MEPC) required the revision of ISO15016:2002 standard and its power correction method [4]. The reasoning behind this was to assess and improve the accuracy of the speed performance determination, due to its importance to Energy Efficiency Design Index (EEDI) calculations. New guidelines were published by ITTC in 2014, [4] and [5] and ISO in 2015, [5] (at the 28th ITTC, in 2017, these recommended procedures were merged into a single one: 7.5-04-01-01.1). These guidelines adopted an improved version of the direct power method which considers the variation

of the quasi-propulsive efficiency with the propeller overload. This method was implemented into the code for the STAIMO software, produced and freely distributed by the Sea Trials Analysis Group (STA-Group – see www.staimo.org).

The propeller overloading effect is considered by three propeller overload factors, for variation of the: quasi-propulsive efficiency, propeller revolution speed and ship speed with the propeller load variation (see Annex J of ISO15016:2015). Normally, these should be determined experimentally by basin self-propulsion tests carried out by the propeller load varying method, aka the British Method. This method is laborious and the constant propeller loading method (Continental Method) is still preferred in spite of it not being able to fulfil the requirements of the latest standard, due to it not being able to produce the propeller overload factors. Both methods are described in [7].

In a previous paper, [8], we proposed a method to calculate the propeller overload factors when only the data of self-propulsion tests carried out by means of the propeller constant loading method are available. This method is suitable when STAIMO code is used in the absence of model tests performed using the British Method. If the actual propeller overload factors are not known, STAIMO code recommends its own default values, yet always the same no matter the ship particularities. In the followings, we propose a method which avoids the calculation of the propeller overload factors.

The proposed method

ISO15016:2015, in Annex J and Annex K, mentions that the variation of the wake fraction, thrust deduction fraction and relative rotative efficiency (propulsive coefficients) with propeller overload are

negligible by comparison with the variation of the propeller open water efficiency. This is the case for most ships having the propeller moderately loaded.

The proposed method is based on this assumption. Propeller open water characteristics, ship resistance and data of self-propulsion tests carried out by the Continental Method are necessary. Therefore, only the power correction method is described here, step by step:

1. For each run of a double run, ship speed over ground (V_G), shaft power (P_S) and propeller revolution speed (n) are measured.
2. Calculate the first approximation of the ship speed through water (V_S) and ship resistance (R_S):
 - a. Calculate the advance coefficient (J) from propeller open water characteristics by assuming the quadratic relationship:

$$K_{Q0} = akqJ^2 + bkqJ + ckq$$

K_{Q0} : propeller open water torque coefficient:

$$K_{Q0} = K_Q \eta_R; K_Q = \frac{Q}{\rho n^2 D_p^5}; Q = \frac{P_S \eta_S}{2\pi n}$$

Q: propeller torque

η_S : transmission efficiency, between the measurement point on shaft and propeller

η_R : relative rotative efficiency

D_p : propeller diameter

- b. Calculate the ship speed through water, V_S :

$$V_S = \frac{V_a}{1 - w_m}; V_a = JnD_p;$$

$$w = 1 - \frac{V_a}{V_G}; w_m = \frac{w_1 + w_2}{2}$$

V_a : advance velocity

w: wake fraction; w_m : averaged wake fraction over a double run

- c. From self-propulsion tests, determine the thrust deduction fraction (t) and relative rotative efficiency (η_R) at V_S
- d. Calculate the ship resistance at V_S from propeller thrust (T) by calculating the propeller thrust coefficient (K_T):

$$K_T = aktJ^2 + bktJ + ckt; T = K_T \rho n^2 D_p^4; R_s = \frac{T}{1-t}$$

3. Calculate the correction of the environment effects on ship resistance, ΔR , by methods available in guidelines. In this stage, the air resistance is totally removed. Hence the index 0 in the relationships of step 4.
4. Correct the measured shaft power and propeller revolution speed for the environment effects:
 - a. Calculate the corrected ship resistance (R_{S0}) and the propeller thrust (T_0):

$$R_{S0} = R_S - \Delta R; T_0 = \frac{R_{S0}}{1-t}$$

- b. Calculate the corrected propeller revolution speed (n_0) by solving the quadratic equation:

$$\frac{T_0}{\rho n_0^2 D_p^4} = aktJ_0^2 + bktJ_0 + ckt; J_0 = \frac{V_a}{n_0 D_p}$$

- c. Calculate the corrected shaft power (P_{S0}):

$$P_{S0} = \frac{2\pi n_0 Q_0}{\eta_s}; Q_0 = K_{Q0} \rho n_0^2 D_p^5; K_{Q0} = \frac{K_{Q00}}{\eta_R}; K_{Q00} = akqJ_0^2 + bkqJ_0 + ckq$$

The above corrected shaft values are at V_S speed through water with no air resistance (in vacuum).

5. Correct the ship speed for current effect and determine the propulsive coefficients at corrected speed:
 - a. Calculate current velocity (V_C) by mean-of-means method or other method in guidelines
 - b. Calculate the corrected ship speed

through water $V_{SC} = V_G + V_C$.

- c. Calculate the corrected wake fraction (w_{SC}) by:

$$1 - w_{SC} = (1 - w_m) \frac{1 - w_{BT}(V_{SC})}{1 - w_{BT}(V_S)}$$

w_{BT} : wake fraction determined by basin tests at V_{SC} and V_S respectively.

- d. Determine the corrected thrust deduction fraction (t_C) and relative rotative efficiency (η_{RC}) corresponding to V_{SC} from basin tests
6. Correct the shaft power and propeller revolution speed determined in step 4 to still air condition, i.e. no current and wind

- a. Calculate the ahead air resistance at V_{SC} :

$$R_{AA0} = \frac{1}{2} C_{AA0} \rho_{air} A_{VT} V_{SC}^2$$

C_{AA0} : head wind air resistance coefficient

A_{VT} : transversal windage area

- b. Calculate ship resistance (R_{SC}) and propeller thrust (T_C) in still air:

$$R_{SC} = R_{S0} \frac{C_T(V_{SC}) - C_{AA0BT}}{C_T(V_S) - C_{AA0BT}} \left(\frac{V_{SC}}{V_S} \right)^2 + R_{AA0}; T_C = \frac{R_{SC}}{1-t_C}$$

C_T : total resistance coefficient at V_{SC} and V_S respectively determined by basin tests

C_{AA0BT} : head wind air resistance coefficient in basin tests

- c. Calculate the corrected propeller revolution speed (n_C) by solving the quadratic equation:

$$\frac{T_C}{\rho n_C^2 D_p^4} = aktJ_C^2 + bktJ_C + ckt; J_C = \frac{V_{aC}}{n_C D_p}; V_{aC} = V_{SC} (1 - w_{SC})$$

- d. Calculate the corrected shaft power (P_{SC}):

$$K_{Q0C} = akqJ_C^2 + bkqJ_C + ckq; K_{QC} = \frac{K_{Q0C}}{\eta_{RC}}; Q_C = K_{QC} \rho n_C^2 D_p^5; P_{SC} = \frac{2\pi n_C Q_C}{\eta_s}$$

7. Calculate the ship speed, propeller revolution speed and shaft power in deep water (V_{SDW} , n_{DW} , P_{SDW}) by

correcting the shallow water effect

- a. Calculate the shallow water speed correction ($\Delta V_{Sshallow}$), by Lackenby method. The shallow water increases the ship resistance. It is assumed that in deep water the ship resistance is the same as that calculated in shallow water, so the ship speed is greater by $\Delta V_{Sshallow}$. The propulsive coefficients in deep water (w_{DW} , t_{DW} , η_{DW}) are assumed also the same. By these assumptions, the ship resistance and propeller thrust in deep water (R_{SDW} , T_{DW}) have the values calculated at 6b.
- b. Calculate the propeller revolution speed in deep water by solving the quadratic equation:

$$\frac{T_{DW}}{\rho n_{DW}^2 D_p^4} = aktJ_{DW}^2 + bktJ_{DW} + ckt; J_{DW} = \frac{V_{aDW}}{n_{DW} D_p}; V_{aDW} = V_{SDW} (1 - w_{DW}); V_{SDW} = V_{SC} + \Delta V_{Sshallow}$$

- c. Calculate the shaft power in deep water:

$$P_{SDW} = \frac{2\pi n_{DW} Q_{DW}}{\eta_s}; Q_{DW} = K_{QDW} \rho n_{DW}^2 D_p^5; K_{QDW} = \frac{K_{Q0DW}}{\eta_{RDW}}; K_{Q0DW} = akqJ_{DW}^2 + bkqJ_{DW} + ckq$$

8. Calculate the final corrected values of ship speed, propeller revolution speed and shaft power by averaging over a double run the above corrected ship speed, propeller revolution speed and shaft power ($V_{SDW\ average}$, $n_{DW\ average}$, $P_{SDW\ average}$).

The proposed method is similar in some respects to Taniguchi-Tamura method, though it has its own particularities:

- a. The corrected power for environment effects is not adjusted to the measured propeller revolution speed. Thus, the fairing of the corrected torque coefficient versus corrected propeller revolution speed, which is not always enough accurate, is avoided;
- b. The corrected advance coefficient, thus the corrected propeller revolution speed, is calculated by solving the quadratic equation in step 6c, not on load factor – advance coefficient diagram;
- c. The propeller open water torque coefficient is calculated by a quadratic polynomial, not linearly approximated.

Parameter	ISO: 2002 method (Taniguchi-Tamura)	ISO:2015 method (direct power)		Proposed method
		STAIMO default propeller overload factors	propeller overload factors calculated by method in (8)	
Service speed (knots)	14.13	14.11	14.25	14.10
Trial speed (knots)	14.61	14.59	14.72	14.57
Trial propeller revolution speed (rpm)	97.94	98.08	97.16	97.32
LRM (%)	5.08	5.24	4.25	4.42

PANAMAX Bulk Carrier

Parameter	ISO: 2002 method (Taniguchi-Tamura)	ISO:2015 method (direct power)		Proposed method
		STAIMO default propeller overload factors	propeller overload factors calculated by method in (8)	
Service speed (knots)	13.98	13.93	13.98	13.98
Trial speed (knots)	14.61	14.56	14.61	14.61
Trial propeller revolution speed (rpm)	70.36	70.51	70.44	70.36
LRM (%)	1.09	1.31	1.20	1.09

CAPESIZE Bulk Carrier

If the accuracy of the quadratic fairing is not enough, a cubic polynomial or numerical method may be used. Then the equations in step 4b, 6c and 7b must be solved numerically;

- d. The ship resistance and propulsive coefficients are corrected for the current effect, steps 6b, 5c and 5d;
- e. The propeller revolution speed and power are corrected after the ship speed is corrected for shallow water effect, steps 7b and 7c.

The shallow water correction was on ship speed, by Lackenby method. If another method is preferred, correcting instead the ship resistance, the corresponding ship speed can be determined by rewriting accordingly the equation of 7b.

Example

In the tables above, the corrected ship speed, propeller revolution speed and shaft power, calculated by the proposed method, ISO2015 method and ISO:2002, are presented. The test ships were a Panamax and Capesize bulk carriers. These methods were individually coded on spreadsheets. The environment corrections were the same, to compare only the effect of the power correction method.

Conclusions

By ignoring the effect of the propeller overload on the propulsive coefficients, the proposed method is fundamentally the same as the Taniguchi-Tamura method adopted in ISO15016:2002. Yet, it has its own particularities which make it distinctive.

The variation of the propulsive coefficients with propeller overload is negligible, as the new guidelines point out. In the new guidelines' direct power method, the effect of the propeller overload/underload due to sea trials conditions is considered by means of the propeller overload factors. They must be determined by self-propulsion basin tests performed by the laborious propeller load varying method.

Most ships have moderately loaded propellers and the variation of the propulsive coefficients may be neglected. The less laborious propeller constant loading method for self-propulsion basin tests is so preferable. The proposed method is a suitable solution for this case. *NA*

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YOUR IDEAS. OUR TOOLS.

Experience with full-scale thrust measurements in dynamic trim optimisation

Data-driven trim optimisation solutions currently rely on a shaft power meter. However, a new study by VAF Instruments suggests that thrust measurements are a valuable input in determining optimum trim

Optimum trim is essential for minimising fuel consumption, but this means that power must be determined for a variety of combinations of trim, speed and draught. This has traditionally been done with full-scale trials and/or model tests [9]. In recent years, the capabilities of CFD have progressed sufficiently that it is economically viable to compute the influence of trim for a multitude of speeds and draughts [4]. Moreover, the maritime industry has become increasingly data driven, making possible the advent of data-driven trim optimisation and machine learning algorithms that can deduce the relation between trim and power based upon data measured when a ship is in service [5].

So technological progress has greatly expanded the options and potential for accuracy with trim optimisation. But another innovation, thrust measurements, can also help in trim optimisation. VAF Instruments has developed the TT-Sense, a device that in addition to being a torque and power meter, can measure the thrust provided by the ship's propellers. This thrust data is of significant value due to the fact it is measured at the shaft, between the propeller and the thrust bearing, allowing for separate analysis of the hull and propeller.

The effects of trim

Because trimming affects the shape of the submerged part of the hull it influences almost every aspect of resistance and propulsion. As discussed by Reichel et al. [8], the change in residual resistance of the ship and the change in propulsive efficiency are the most important influences on the required propulsive power.

Residual resistance is primarily influenced by changes to the wave pattern that is generated by the ship. For ships with bulbous bows in particular, the effect of trim on the wave pattern can be significant. A favourable trim will mean a favourable wave pattern

where less energy is dissipated.

Because the flow around the hull changes with trim it affects a ship's propulsive efficiency. This causes the thrust deduction factor and wake fraction to change resulting in changed hull efficiency (η_h). Moreover the propeller starts to operate in a different wake and therefore the propeller efficiency (η_p) changes. A favourable trim will result in a favourable flow pattern around the hull so that less power is lost by the propeller.

An important distinction has to be made between static, i.e. at the start of the voyage, and dynamic trim, which is the trim during a voyage. When the operating conditions are known in advance, it is possible to anticipate the dynamic trim based on the static trim, and vice versa. Trim optimisation software can both give a static trim advice before setting off, and a dynamic trim advice while sailing. This paper trim focuses on dynamic trim.

Predicting the effects of trim

To predict the effects of trim one must correctly determine the change in (residual) ship resistance and the change in propulsive efficiency. Therefore, both the hull and propeller need to be correctly captured. The three modelling methods that can be used are the model test approach, the CFD approach and the data-driven approach.

In the model test approach self-propulsion tests will need to be performed to take into account both the hull and the propeller. To account for viscous scale effects corrections will have to be made, translating the model results to full scale, but since the hull and propeller adhere to different scaling laws they need to be treated separately. These full-scale corrections are the biggest source of uncertainty with model scale tests, but can be kept to a minimum in the controlled environment of a towing tank.

Full-scale CFD computations eliminate the influence of scale effects. But different CFD

models adopt different approximations in modelling viscous effects, which also creates uncertainties. Moreover the use of numerical methods introduces a numerical uncertainty. The propeller is generally modelled separately from the hull, and the models then combined e.g. in the approach taken by Hansen and Freund [4].

The data-driven approach, which we are focusing on here, utilises full-scale data measured during regular ship service, alleviates the drawbacks of model testing and CFD. However, new uncertainties arise given that the measurements are dependent upon changing external factors (wind, waves, temperature etc.) that are not present during a model test. This translates into more scattered data than a model test.

Trim optimisation based on the full-scale measured data relies on machine-learning algorithms that are able sift through this noisy and uncertain data. There are many choices to make in the selection of the machine learning model and the relevant parameters it takes into account (feature selection), meaning that a different optimal trim may be arrived at from the same data. [7].

CFD computations and model tests can look at the influence of trim on the hull and the propeller separately, but the data-driven approach relies solely on the power meter. Optimal trim can be predicted based on power only, but it lacks the additional insight that the other two methods can give.

Another drawback is data scarcity. When conducting experiments or computations, a predetermined matrix of draught, speed and trim can be accounted for such that there is a knowledge base covering all operational conditions of a ship, even those it rarely encounters. But a trim optimisation model that learns 'on the job' from data obtained in service may not give rise to accurate predictions in newly encountered conditions simply because it does not yet have the data to do so [2].

The user must also mitigate what is known as the ‘curse of dimensionality’. This is a problem that occurs with high-dimensional data because with an increase in dimensions the volume spanned by those dimensions rapidly becomes larger, effectively making the data more scarce. Optimal trim prediction of the machine-learning model can be improved by reducing the variables [7].

Advantages of using thrust measurements

Let us now consider how the measurement of thrust might be used to the advantage of data-driven trim optimisation by separating hull and propeller.

Suppose a ship travels continuously at exactly the same speed. When the hull resistance increases because of the adoption of a sub-optimal trim, the power required to propel the ship will increase and means the thrust delivered by the propeller must rise to match the increased resistance.

But suppose that only the propeller’s efficiency decreases due to a sub-optimal trim. There will still be an increased power requirement, but because the hull resistance stays the same the propeller will not have to deliver an increase of thrust. Hence there are clear benefits in thrust measurements that make a distinction between the respective performance of the propeller and the hull.¹

This is particularly advantageous when there are influences aside from trim that affect performance of one but not the other, such as ships equipped with a controllable pitch propeller (CPP). In contrast to a fixed pitch propeller (FPP), a CPP can deliver the same amount of thrust at different rotation rates; the efficiency will depend on the chosen pitch and will therefore affect the power needed.

Supposing a ship sails with a speed of 14 knots and a draught of six metres, with a low value of trim and relatively low power consumption. This data point is provided to the trim optimisation software which learns from the experience. Two weeks later the ship sails again at exactly the same speed and draught, but now has a high value of trim and high power consumption. However, its CPP now has a different pitch and efficiency than two weeks earlier. The increase in power cannot be ascribed to the high value of trim, because it may be a result of the difference in propeller pitch. Therefore, when power measurements are used to optimise trim the

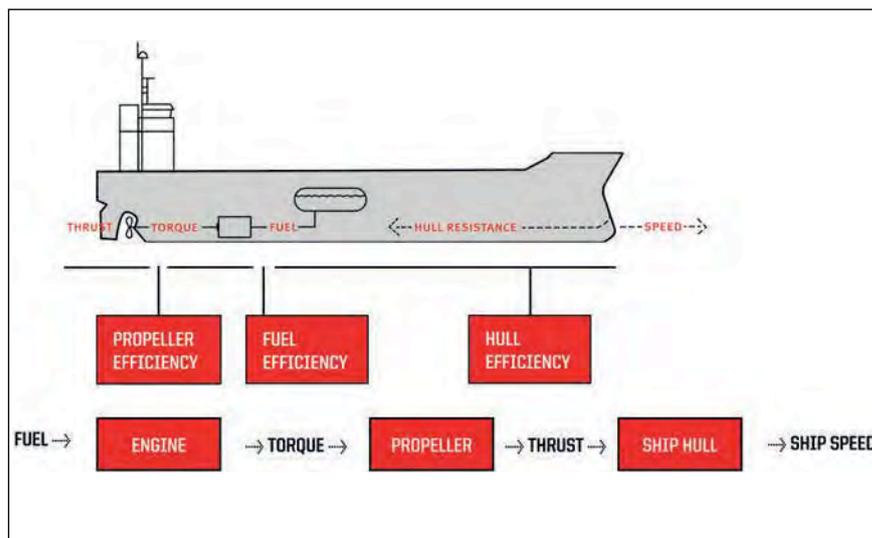


Figure 1: Only by measuring thrust can propeller efficiency be separated from hull resistance

change in propeller pitch (efficiency) must be taken into account.

Suppose the same hypothetical ship had used thrust measurements to optimise trim. At a low value of trim it turns out a relatively low thrust was needed to overcome the resistance of the ship. Two weeks later when it sailed at a higher trim it turns out that less thrust was needed, in other words hull resistance had decreased. When thrust measurements are used to optimise trim, the CPP efficiency is no longer relevant, meaning there are fewer variables to account for.

A sensibly designed ship will have an optimised hullform shape complemented by an optimised propeller tailored to fit. In general one can expect the propeller to operate most efficiently in those cases where the hull resistance is lowest. The optimal trim value can thus be found relying on thrust measurements.

Case study

To demonstrate the usefulness of thrust measurements, let's consider some full-scale data derived from TT-Sense to compare the effect of trim on power with that of trim on thrust. This case study encompasses a month of continuously monitored data on a vessel with a length between 200- 300 meters,

equipped with an FPP. No machine-learning algorithms were used in the case study.

For this case study, the variables considered are thrust, power, trim, speed through water, draught, wind speed and water depth. Thrust and power were measured by the TT-Sense. As discussed by Ballegooijen and Muntean [1], the working principle of the TT-Sense is based on measuring shaft compression and torsion. Optical sensors detect the small displacements over the shaft length, in both axial and tangential directions, corresponding to the compression (thrust) and torsion (torque) of the propeller shaft. The optical measurement principle allows for an independent measurement of both the thrust and the torque. Torque, combined with the measured rotation rate, is used to compute power, see Figure 3.

Trim was measured by two draught sensors positioned near the bow and the stern of the ship. Unfortunately this is not the most accurate way of measuring trim, since the sensors are sensitive to variations in speed. To mitigate this problem, the ensuing analysis the results will be presented in very narrow ranges of ship speed. However, for future studies it is preferable to use a dedicated instrument such as an inclinometer.

¹ In reality there are interaction effects between propeller and hull that make matters more complicated, and one would need to measure flow speeds in the ship's wake to resolve this. As this is not practical the pragmatic approach is chosen to apportion the increase in required power that can be linked to an increase in thrust to the hull, and the remainder to the propeller.

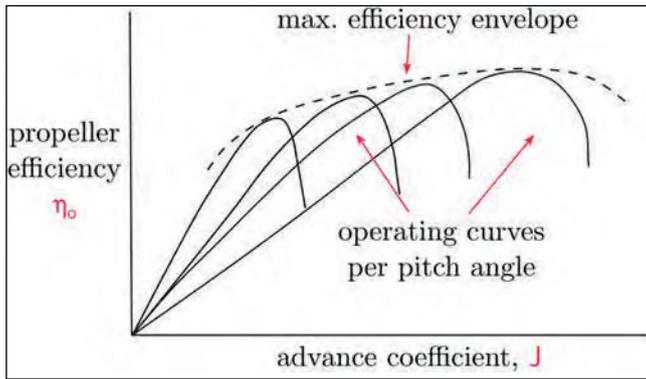


Figure 2: Schematic graph of propeller efficiency and pitch (CPP)

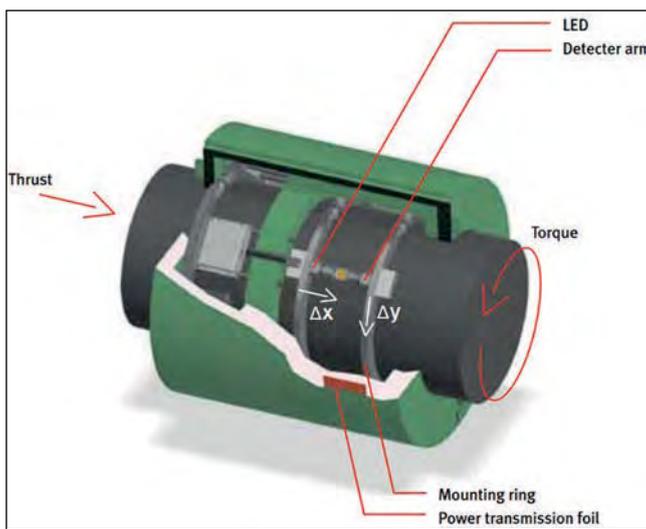


Figure 3: TT-Sense Thrust and Torque Sensor

Speed through water was measured by the speedlog. While this is not always a reliable instrument, in this instance the speedlog data used did not show any obvious signs of error. Draught sensors located near midship were used to measure the draught of the ship, wind speed was recorded with an anemometer and a depth gauge for the water depth.

To isolate the specific effect of trim on power and thrust, the data is carefully filtered to minimise the external influences. Firstly data is only taken from those periods in time during which the ship was travelling at a near constant speed. In addition, it has been filtered for deep water and low wind speeds so that the influences of shallow water effects, waves and wind are negligible. For the sake of clarity and transparency no corrections or alterations have been applied.

From the filtered data, three subsets are selected of narrow ranges in draught and speed. In each subset, both the draught and speed are only allowed to vary within +-2% of their mean value. This ensures that the influence of draught and speed variations is

small enough that only the relation between trim and thrust and power remains.

Even within this narrow speed range there is a noticeable dependency of power on speed, which is to be expected, considering power relates roughly to the cube of speed. In order to further remove the influence of speed, the power was therefore made adimensional with the cube of speed. Analogously the thrust was made adimensional using speed squared. In order to compare the influence of trim on both power and thrust in the same graph they need to share the same axis. This is achieved by dividing the adimensional power and thrust of each individual data point in a subset, by the average of the adimensional power and thrust of all data points within that subset. The resulting variables are:

$$P^* = \frac{P}{\langle \frac{P}{v^3} \rangle} \quad T^* = \frac{T}{\langle \frac{T}{v^2} \rangle}$$

P^* denotes a relative power, while T^* denotes a relative thrust. A data point

having a P^* of 1 needed the expected, average amount of power. A data point with a P^* of 1.05 needed 5% more power than the average, and with a P^* of 0.95, 5% less. The same goes for thrust. When it is approximated that effective towing power is linearly related to thrust, a 5% increase in T^* equates to a 5% increase in towing power. If both P^* and T^* increase with 5%, that means the propeller efficiency remained equal, and the increase in power can be ascribed entirely to an increase in hull resistance. If for a certain trim the increase in P^* is larger than the increase in T^* , there has been a decline in propeller efficiency.

Results

Measured thrust and power data from the TT-Sense will now be shown as a function of trim. This will be done for three operating conditions of the same draught but different speeds: 14, 14.5 and 18 knots.

Figures 4-9 show the measured values of thrust and power, converted to the adimensional values T^* and P^* respectively. All values were sampled while the ship sailed in similar conditions: calm weather, deep water, and with only +-2% variation both in ship speed and draught. By mitigating the influence of other parameters, the thrust and power are only dependent on trim. The figures can thus be used to estimate the dependency for the applicable operating condition.

In Figures 4, 6 and 8 the thrust and power values are shown side by side. In Figures 5, 7 and 9 the exact same data points are shown again within the same graph. For the latter set of figures a polynomial fit has been drawn through the datapoints in order to highlight the differences between them. The polynomial fits are purely indicative; they are meant to show the general trend.

Discussion

The measurements of power and thrust show a similar relationship to trim in the three cases. Moreover, the derived relationships between trim, thrust and power are plausible.

The trim value where thrust is smallest is almost the same as the trim where required power is smallest. However, where T^* has a low value, P^* has an even lower value. This means that the decrease in required power cannot be accounted for only by the decrease in hull resistance, but that the propeller is

more efficient in those cases as well. As was hypothesised, the propeller appears to be most efficient when the hull resistance is at its smallest. The reverse also applies; when T^* is large, P^* is even larger, indicating that the propeller experiences an unfavourable wake when hull resistance is greatest.

While the polynomial estimation suggests even lower values, the majority of the data indicates a most optimal P^* of about 0.95. This means that by always sailing at the most favourable trim the ship under investigation can save about 5% in propulsive power consumption compared to how it is currently trimming. These results roughly agree with values reported by commercial parties (see [9], [5], [4] and the overview given in McMillan and Jarabo [6]).

For the operating condition at 14knots there is a good amount of data spanning the entire range of trim. For the other two operating conditions however, there is data missing for certain values of trim., simply because the ship never sailed in such a

condition. In Figure 9 between 0.1-0.8m trim the polynomials for thrust and power predict opposing trends, without there being any data to justify this. This exemplifies the problem of data scarcity; even though trim optimisation software will make a much more sophisticated estimate than a simple polynomial, a generalisation will inevitably be made without data to validate it.

Conclusion

There is a promising potential for improving data-driven trim optimisation by incorporating thrust measurements in addition to power measurements. The information on thrust allowed for a separate measurement of trim effects on the hull and the propeller, especially helpful when dealing with CPPs.

The FPP investigated in the case study seems to perform best when the hull resistance is low and worse when hull resistance is high. Consequently, the trim value that minimises hull resistance is very

close to that which minimises total power. An interesting next step would be to build a proof of concept of trim optimisation using thrust data. Additional research with more data of ships (with CPPs) could help support this.

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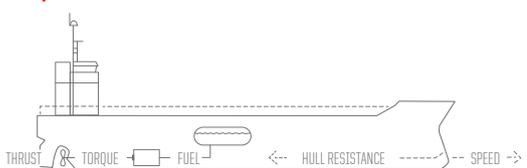
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Figure 4: Side by side display of thrust and power at 14 knots

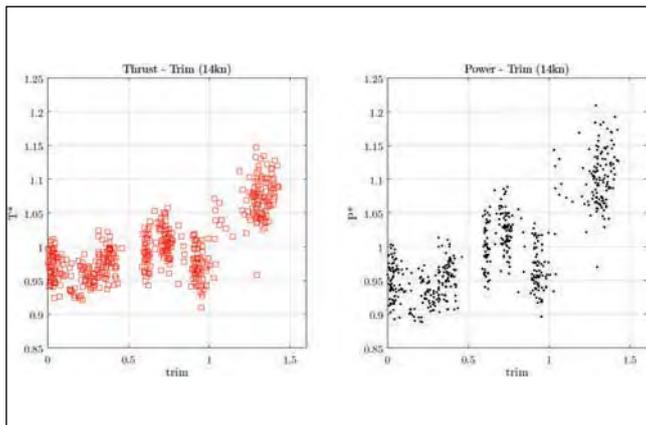


Figure 5: Direct comparison of thrust and power at 14 knots

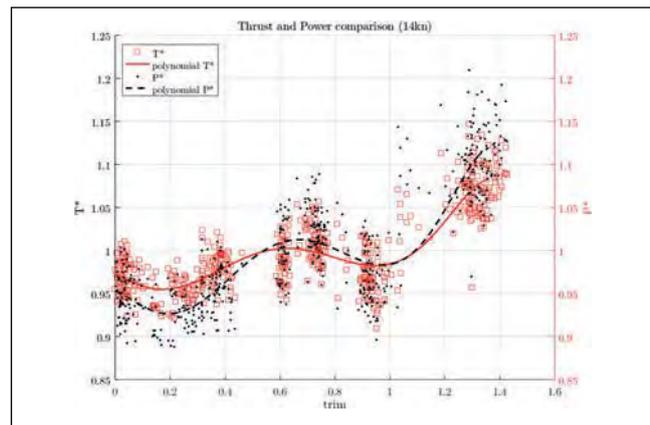


Figure 6: Side by side display of thrust and power at 14.5 knots

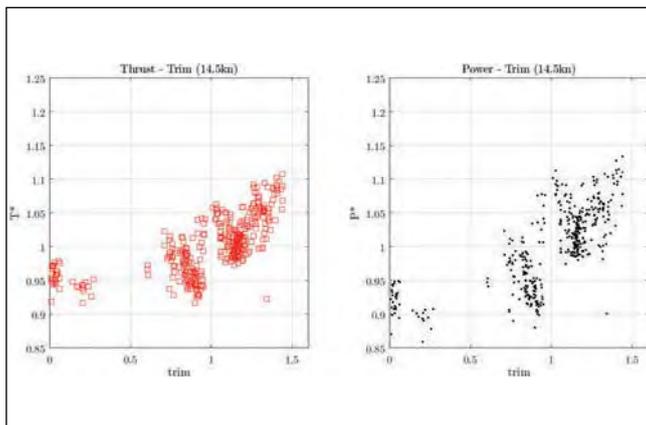


Figure 7: Direct comparison of thrust and power at 14.5 knots

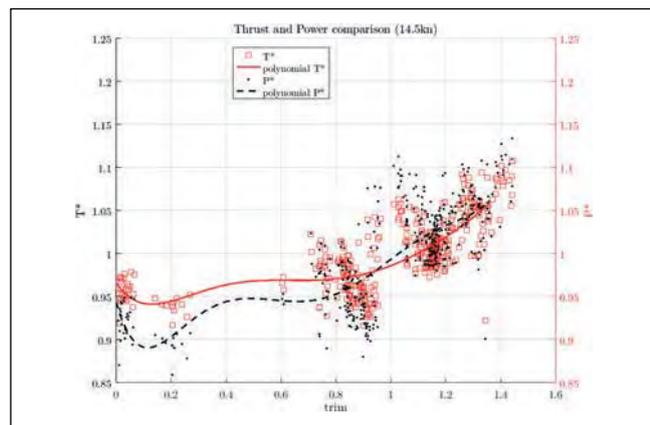


Figure 8: Side by side display of thrust and power at 18 knots

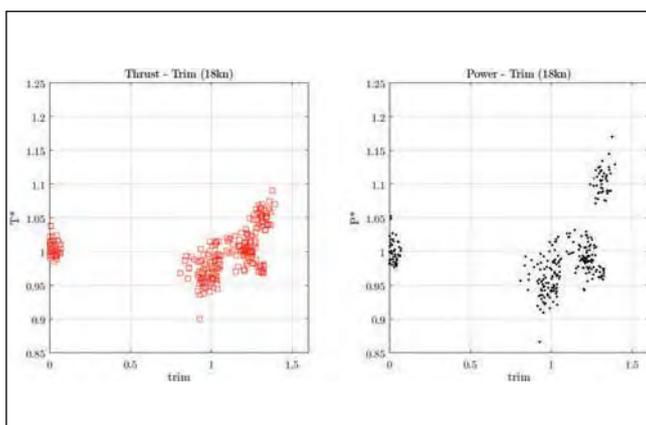
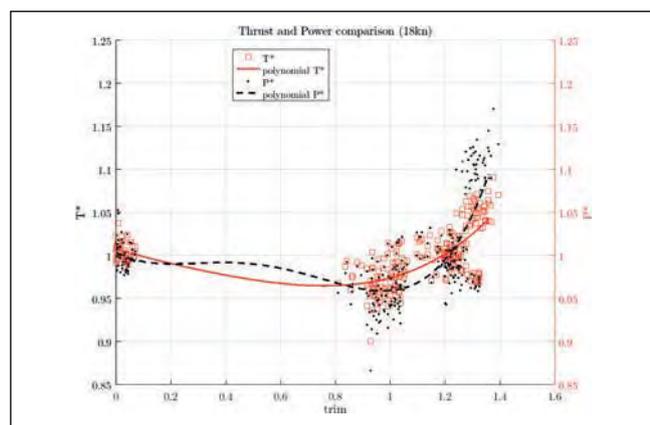


Figure 9: Direct comparison of thrust and power at 18 knots



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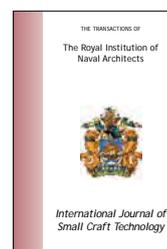
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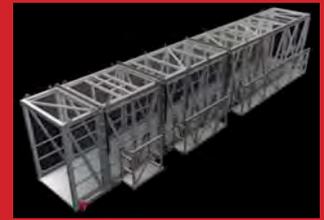
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