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Editor: Richard Halfhide
Assistant Editor: Joseph Stewart
Design/Production Manager: Sandy Defraigne
Advertisement Production Manager: Stephen Bell
Subscriptions & Publications Manager: Tasharna Francis
Publisher: Mark J Staunton-Lambert

Advertising Sales: J P Media Services
 Email advertising: jpayten@jpm mediaservices.com
 cseldon@jpm mediaservices.com
 Telephone: +44 (0)1737 852135

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Smarter thinking

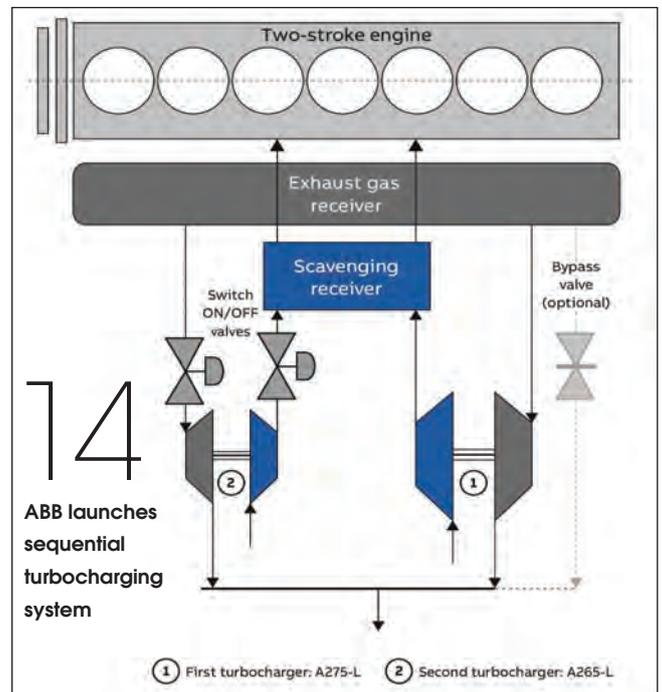
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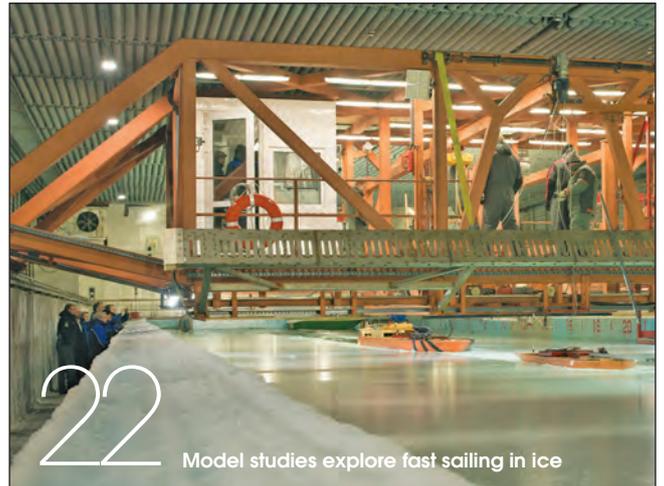
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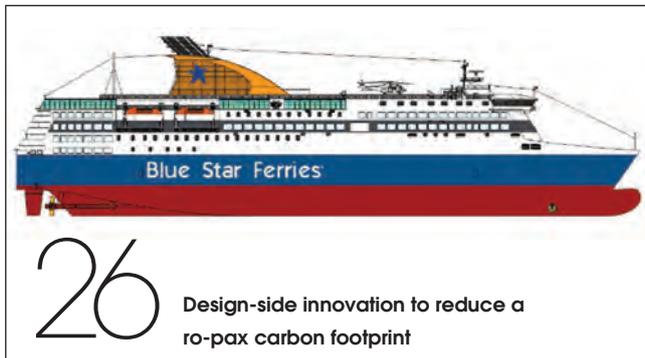
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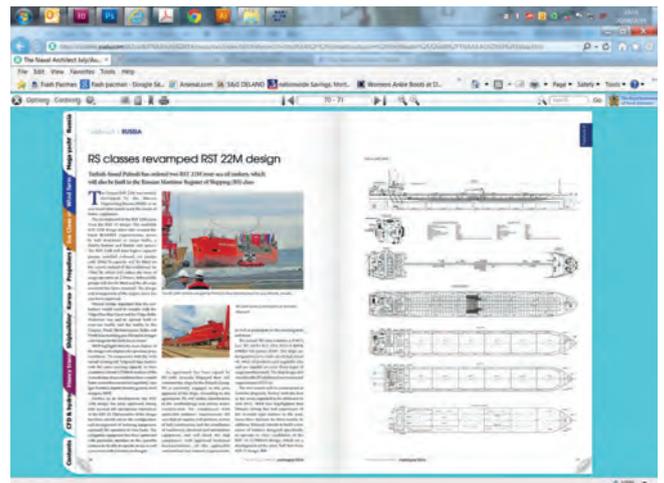


Selektope impress with two-year trial results

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Smarter thinking

The Smart Marine Ecosystem: Wärtsilä's vision of shipping's future

The word 'ecosystem' was first coined by the botanist Arthur Tansley in the 1930's to describe the transfer of materials between organisms and their environment. Its use remained firmly rooted in the ecological domain until the 1990's, when academics began using the word as an analogy to refer to the interaction of different goods and service providers, and its bearing upon strategic planning.

But to talk about the 'business ecosystem' suggests a certain harmonic balance which belies the harsher, rapacious realities of business. Indeed, an even more fashionable buzzword, 'disruption', has entered the vernacular to describe the challenge to the old equilibrium posed by new business models and emergent technologies.

The marine industry is more innately conservative than one finds in the cut-and-thrust of Silicon Valley or consumer electronics. Change never occurs overnight and, if it has any bearing upon safety or the environment, is liable to be debated at length by IMO and other administrative bodies. This means that older, established players in marine technology have time to consider their options, not to mention possessing resources that allow them to acquire and assimilate newer companies and expand their capabilities.

One such company is Wärtsilä which, by way of example, in October last year acquired Guidance Marine, which specialises in sensors for vessel control systems, including collision avoidance and remote control operations. It marked another step towards Wärtsilä's vision of a 'Smart

Marine Ecosystem', which was launched in late November. Not so much a specific service as a guiding philosophy with which to market its products, Wärtsilä has identified four 'primary forces' which it believes will reshape the industry: *shared capacity* to reduce costs, *Big Data analytics*, *Intelligent Vessels* and *Smart Ports*.

Speaking at the press launch Roger Holm, President, Wärtsilä Marine Solutions, said: "We need to start looking at things from a more holistic approach. Not just equipment and fleet, but the total picture. We are moving slowly but surely towards a 'vessel-as-a-service' concept. It will take quite a long time but we will begin to see bits and pieces coming into this plan; looking at how we optimise the lifecycle starting with how we design it."

Wärtsilä's vast portfolio makes it ideally positioned to capitalise on any such paradigm shift. Among recent innovations it was keen to highlight were the successful trials in remote controlling a vessel using a standard bandwidth satellite connection, the Wärtsilä HY hybrid power system and wireless charging for battery powered vessels. It has also launched the first of four Digital Acceleration Centres (DAC) in Helsinki, which uses a unique 'Dragon's Den' style format to brainstorm and quickly co-develop new concepts with customers, including a design project for what it describes as the industry's most advanced intelligent vessel.

Wärtsilä concedes that the 'ecosystem' is too big a project for just one company, but quite how (or if) it will collaborate with its marine tech rivals (e.g. Rolls-

Royce, ABB) remains decidedly vague. In order for such a vision to become reality requires the establishment of standards, particularly with regard to digitalisation and data sharing. While progress may be inevitable, shipowners can hardly suspend operations while the blueprint for this utopian future is prevaricated over.

Holm also suggested that smaller, nimbler shipowners may be better suited to assimilate and embrace change. It's certainly true that they're less disposed to absorb the costs of inefficiencies, making it easier to appeal to them on those grounds.

Reading between the lines one might suspect a bid by the technologists to wrestle control of shipping from the hands of the builders and owners towards to a deeper symbiosis that will favour them, shifting more investment into opex. That shouldn't be interpreted as a slight towards Wärtsilä and their competitors, who are among the most progressive figures you will find in the marine industry. But it would require an extinction level event for radical change to happen anytime soon, so for now the old 'dinosaurs' will continue to be their biggest customers.

More plausibly the next few years will see continued emphasis on service-based agreements, such as the billion dollar deal Wärtsilä signed with Carnival to provide engine maintenance and monitoring for its entire fleet. The capability may exist to rebuild shipping, but in a perpetually uncertain climate, consolidation is still the prevailing sentiment. *NA*

LNG

Tank deal is 'more than a game-changer' says GTT

LNG specialists GTT have sealed the contract to design the cryogenic tanks for nine LNG-fuelled container ships to be built by Hudong-Zhonghua Shipbuilding Group, a member of China State Shipbuilding Corporation (CSSC).

It was announced in August 2017 that Hudong-Zhonghua and its sister yard, Shanghai Waigoqiao Shipbuilding Co, had won the order from CMA CGM for the 22,000teu vessels, undercutting competition from the likes of South Korea's Hyundai Heavy Industries (HHI). Upon delivery, due to take place between late 2019 and late 2020, they will become the world's largest container ships, eclipsing the *OOCL Hong Kong*. The vessels will come with 18,000m³ fuel tanks, the largest yet seen on oceangoing vessels and a capacity which exceeds that of smaller LNG carriers.

Philippe Berterottière, GTT's chairman and CEO, heralded the order as the dawning of a new epoch for LNG. He tells *The Naval Architect*: "Previously it has been very small tanks but now the owner is giving himself the possibility of going all the way around the world and back without bunkering. That is more than a game-changer, it's a business model where the owner is putting himself in a situation where he's going to be able to benefit from the lowest LNG prices, anywhere in the world, whether it's American or Asian LNG."

Having provided the 266,000m³ containment tanks for Qatar's Q-Max series of very large LNG carriers, not to mention the FLNG *Prelude*, which has 320,000m³ of storage spread across eight tanks, GTT was perhaps the inevitable choice for such a project. But the unique shape of the tanks, with a wide beam of 50-51m but only 25m length, will pose a unique design challenge and require particular attention to the liquid motion.

The tanks will be built to an upgraded version of GTT's Mark III membrane system, known as Mark

III Flex. Berterottière explains: "Because with our particular technology the tank is integrated to the hull, we are able to put more LNG into a given space compared to the Type 'B' [Moss tanks] or Type 'C' [cylindrical tanks] technology. We use the traditional thickness of the Mark III, 270mm, with a high density foam in order to provide the strength capable of coping with the liquid motion the tank is going to see."

The tanks will all be built by Hudong-Zhonghua, who are also building five of the vessels, with four of the tanks then being transported to Shanghai Waigoqiao, where the remaining vessels are to be built.

See also *China Ship News* p18-19

Artificial intelligence

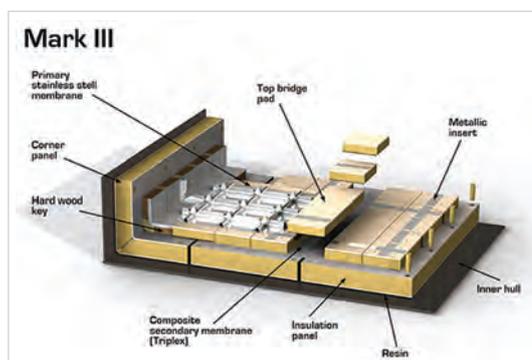
Eco Marine Power researching AI tech

Japan-based marine technology company Eco Marine Power (EMP) has announced plans to use Sony Network Communications' Neural Network Console as part of a study aimed at incorporating Artificial Intelligence (AI) into ship technology projects.

As featured in November's *Naval Architect*, EMP, founded by RINA fellow Greg Atkinson, is already making strides with its Aquarius MRE system, a renewable energy solution which integrates rigid sails with solar panels. The study will explore how the Neural Network Console, an 'integrated development environment' which uses deep learning for AI creation, can assist with improving the automated control system for EMP's Energysail. The system adjusts the sails according to factors such as wind speed and direction.

Atkinson says: "All of our solutions include a level of automation, however we see opportunities to expand on this using AI and deep learning to control algorithms, analyse results and develop future systems. In addition we intend to explore how recognition technology and sensors can be integrated together to control not only our systems, but other systems and equipment on ships, especially in regards to the use of renewable energy."

GTT's Mark III membrane system



Ship design

C-Job opens international office

C-Job Naval Architects, the Hoofddorp, Netherlands, headquartered ship design and engineering company, has launched its first international office in Nikolayev, Ukraine.

Twenty full-time engineers will be based at the new premises, which the company says will increase

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its capacity to offer design and engineering solutions to the global market. The new subsidiary, C-Job Nikolayev, will collaborate fully with the three offices in The Netherlands.

C-Job Nikolayev's managing director, Andrey Zhrebetsky, was keen to emphasise the area's rich maritime heritage: "Nikolayev – with numerous shipyards and the respected Admiral Makarov National University of Shipbuilding – is the centre of the shipbuilding industry in this region."

He adds: "The financial advantages are obviously important – we can deliver European standards of ship design and engineering at Ukrainian costs – but we have an excellent range of skills here."

"Depending on the client's needs, we can deliver engineering packages with a wide range of software – Cadmatic, Siemens NX, Inventor, Intergraph, Rhinoceros 3D, ANSYS, Siemens Femap and AVEVA – all within the specific requirements of shipyards and ship owners."

Newbuildings

SDARI-designed 'smart ship' launched in China

Great Intelligence, a 38,800dwt modified version of the earlier fuel-efficient *Green Dolphin* bulk carrier concept, was officially unveiled at a special launch ceremony in Shanghai as part of Marintec China in December.

Designed by Shanghai Merchant Ship Design and Research Institute (SDARI), and built at CSSC's Guangzhou Wenchong Shipyard, the vessel is being described as China's pilot 'smart ship' project, having attained Lloyd's Register's (LR) descriptive notes for a cyber-enabled ship (CES).

Guidance issued by LR in 2016 established what constituted a CES as well as the provisions which needed to be taken to ensure these did not pose a safety risk.

Great Intelligence will be operated by SinoTrans Shipping for transporting coal and salt between China, Australia and Southeast Asia



Great Intelligence's smart system included features, such as the Ship Operation and Maintenance System (SOMS), which monitor aspects such as the health of the vessel's main equipment, energy efficiency and the intelligent integration of this data to assist with data management, analysis and forecasting.

Another significant feature is the Intelligent Navigation System, which collects data from ship and shore-based service stations and analyses it against baseline route information to identify opportunities for route optimisation, although it will not be capable of acting autonomously.

Li Xin, Innovation Centre Smart Ship Project Vice Director, SDARI, says that the company reimagined the original *Green Dolphin* concept as a digital ship, rather than simply applying the smart systems. He adds: "After the delivery, *Great Intelligence* will be an example of what a smart ship is and make shipping safer, more economic and more efficient."

LNG

Ballast-free ship design gets approval

GTT and Dalian Shipbuilding Industry Co (DSIC) have been granted Approval in Principle (AIP) by Lloyd's Register (LR) for a ballast-free LNG carrier concept, it was announced at Marintec China, Shanghai, in December.

A prototype for the 30,000m³ B-FREE is now clear for further development. Although there are few details at this stage, the companies say the design incorporates a number of innovations and will use GTT's membrane technology for its LNG storage, rather than Type C tanks, which will result in less LNG boil-off.

Ma Yingbin, vice chief engineer, DSIC, says that while the project is a work in progress the companies are confident it will achieve its goal of a ballast-free vessel that is equal or better than conventional designs. "The cumulative improvements in operating costs coming from the combination of the various innovations and new ideas applied to the design are better than we anticipated," he adds.

Cost savings are anticipated through the avoidance of fitting a ballast water treatment system (BWTS) and the Performance Standard for Protective Coatings (PSPC) for ballast tanks, pipes and pumps. The companies also say that initial predictions indicate a lower fuel rate consumption.

David Colson, GTT's VP of commercial, says that the ballast-free concept was first explored several years ago but had now reached the conceptual stage thanks to the work of the DSIC R&D Institute and LR's support. He adds: "The first results show that this ballast-free design has also introduced complimentary advantages such as the reduction in the number of cargo tanks, handling equipment, engine power and more. We are excited to move to the next stage." **NA**

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GHG Roadmap may steer a tortuous course

IMO Assembly meetings are usually a rubber stamping exercise but the latest meeting was somewhat different, writes Malcolm Latache

The 30th Assembly, which took place from 27 November - 6 December 2017, served as both an appraisal of IMO's direction and marked the adoption of its strategic plan for 2018-2023. The outcomes included a revised mission statement, a first vision statement and seven newly-identified strategic directions to tie in with the United Nations Sustainable Development Goals and the 2030 Agenda for Sustainable Development.

The vision statement is perhaps a reaction to the pleadings of the shipping industry for a level playing field and that IMO, rather than other bodies (notably the EU), be recognised as the only point for international shipping regulations. As well as claiming the regulatory leadership role, the vision extends to promoting "greater recognition of shipping's importance and enabling the advancement of shipping, whilst addressing the challenges of continued developments in technology and world trade; and the need to meet the 2030 Agenda for Sustainable Development".

Of the seven strategic directions, some are concerned with making the IMO more effective in developing regulation and taking account of technology. One of them could easily be considered a reaction to the almost farcical implementation of the 2004 Convention on Ballast Water Management and is aimed at getting better feedback from Member States and the industry and improving the way IMO learns from experience and feeds those lessons back into the regulatory process.

Arguably, the one that will cause the most issues in the short term involves developing appropriate and ambitious, but realistic, solutions to minimise shipping's contribution to air pollution

and its impact on climate change. Shipping has had a rough ride on CO₂ despite being the only industry to have adopted global efficiency targets.

Two decades ago, when the Kyoto Protocol was adopted, shipping (along with aviation) was specifically excluded from any national controls on greenhouse gases with the IMO being tasked to look after shipping. IMO's response has been the mandatory Energy Efficiency Design Index (EEDI) – in place since 2013 and now halfway through the first reduction phase – and the mandatory but effectively toothless requirement for Ship Energy Efficiency Management Plans (SEEMPs).

At COP21 in 2015, nation states once again confirmed their commitment to excluding shipping from the Paris Agreement on CO₂, despite pressure from environmental groups. Since then the EU and some shipping industry bodies have felt compelled to push for shipping to at least have ambitious targets. France, Germany, Denmark and Norway have been particularly vociferous and following its re-election to the IMO Council in December, France stated its intention to involve itself in particular in the adoption of an ambitious CO₂ strategy.

Earlier this year, trade associations BIMCO, Intercargo, ICS and Intertanko jointly submitted a proposal to the IMO to adopt two 'Aspirational Objectives': to maintain international shipping's annual total CO₂ emissions below 2008 levels, and to reduce CO₂ per tonne of cargo transported one kilometre by an average of at least 50% by 2050, compared to 2008.

In addition, the four suggested IMO should consider the further objective of reducing international shipping's total annual CO₂ by an agreed percentage by

2050 compared to 2008. Those proposals are included in a draft resolution to be discussed at MEPC 72 in April 2018 along with others that propose reductions by as much as 90%.

The earliest such dramatic reductions would take effect is presently considered to be 2030, but that being achieved would require radical and almost immediate changes to current practices and ship designs. What those changes might be will be the subject of intense debate.

MEPC 72 in April will be the first opportunity to gauge in which direction the IMO and other interested parties are moving. The technical challenge of meeting targets should not be underestimated. Of all options currently available, only switching to LNG achieves any major reduction in CO₂, but this is expensive and only available to a relatively small number of ships. Nor is LNG without problems of its own, such as methane slip.

Another alternative, battery power, is suited mainly to small ferries although some tugs and other ship types could operate partially on battery power for short periods. Hydrogen has its proponents, but even they generally agree that its use as a replacement for fossil fuels is some way off. Some efficiencies will be achieved through hull design advances, but over time these incremental improvements are getting smaller.

It remains to be seen how far the shipping industry will go to implement efficiencies. In early December, it was reported that Emanuele Grimaldi, the head of Finnlines and ICS vice-chairman, expressed the view that shipping should be careful about what the sector promises. No doubt some will see this as the industry rowing back on promises but others will consider it as acceptance of reality. **NA**

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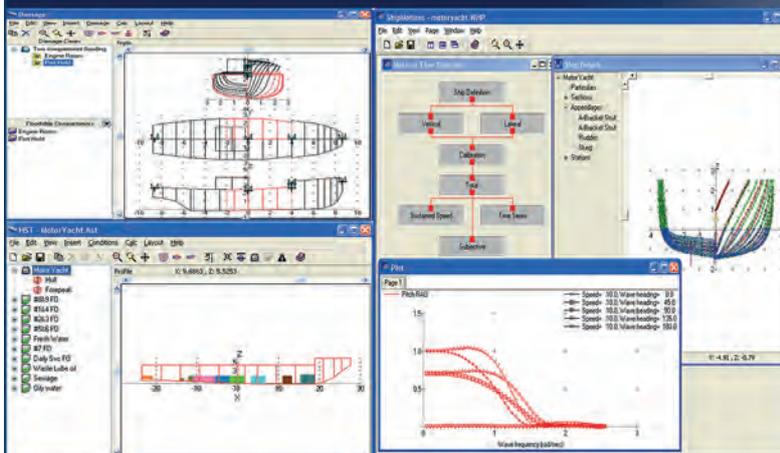
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Turbochargers

ABB pushes turbocharging solutions at Marintec

Swedish-Swiss engineering giant ABB used December's Marintec shipping expo in Shanghai to showcase a range of products and services, including a new sequential turbocharging system.

ABB Turbocharging says the Flexible Integrated Turbocharging System for Two-Stroke Engines (FiTS2) will allow for greater flexibility and lower fuel consumption for vessels with two-stroke propulsions, with savings of up to three percent depending on the vessel's load profile.

Driven by increasing demand for slow steaming of large cargo ships, outside the vessels' original demand parameters, the system will offer improved turbocharging by operating with just one turbocharger when the engine runs at a lower load, while two turbochargers will operate simultaneously at higher loads (50-60% engine load). For very large engines the FiTS2 will be able to run with either two or three turbochargers on the same principle. The FiTS2 will use compact cut-off valves integrated with the turbocharger casings which operate automatically without disrupting the engine.

By cutting out one turbocharger at lower loads, ABB says the system will have increased scavenging air pressure, thereby increasing the compression ratio and firing pressure. This will enhance engine efficiency while remaining compliant with NOx emission limits. It adds that the robust design

and wide compressor maps of the ABB A100-L and A200-L turbocharger series will prevent surging while switching under load with no need for additional bypass valves or pipework.

Joachim Bremer, head of ABB's low-speed product line, believes the potential savings for larger vessels using the FiTS2 could be significant. "Considering a typical current fuel bill of US \$3-4million per year for very large crude carriers, FiTS2 has the potential to provide fuel cost savings of up to US \$100,000," he says, adding that the initial cost can be recovered in less than two years.

ABB says it is enhancing digital connectivity and integrated reporting for turbocharging systems, making data for speeds, temperatures and loads more transparent. Also announced was an expansion of its Sicherheit-skonzep (Safety Concept), otherwise known as SIKO. ABB Ability Digital SIKO, which will initially be available for two-stroke engines, will calculate the ideal time at which to exchange turbocharger components based on actual operation, thereby potentially extending their operational life and cutting costs.

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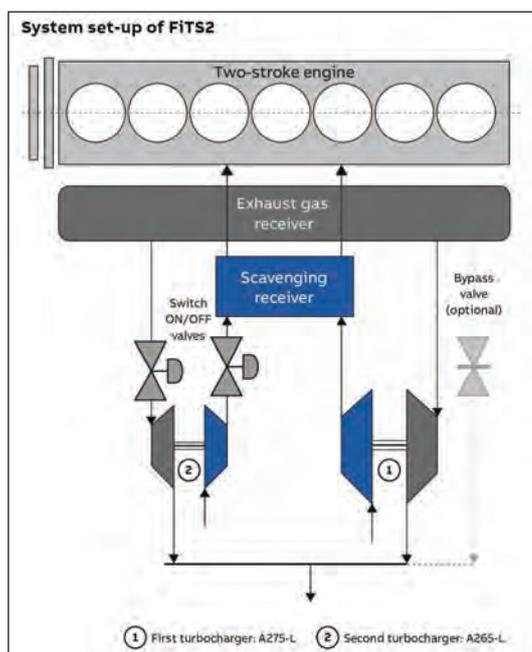
Shell Marine is celebrating a contract to provide marine lubricants and technical services to seven of COSCO Shipping Lines' new generation of 20,000teu Ultra Large Container Carriers (ULCCs), it was announced in December. The vessels, which were ordered in 2015, are due to enter service over the next two years.

The deal consolidates Shell's strong relationship with the Chinese operator, for which it has supplied services to more than 140 vessels since 2004. COSCO is also in the process of a takeover of Orient Overseas Container Line (OOCL), which owns the world's current largest container ship, *OOCL Hong Kong*, for which Shell coincidentally signed a lubricants and services deal in 2017.

Jan Toschka, Shell Marine Executive Director, said that customer engagement had been key to the new COSCO deal, which includes onboard testing and assisting COSCO with onboard blending, oil drain monitoring, and customised analysis and feedback, in a report provided in Chinese language. It has also positioned a 'Technical Maritime Hub' in Shanghai which will have technical experts at COSCO's disposal. The contract "demonstrates owner preferences for proven lubricant performance, supported by a global logistics network and comprehensive technical services," says Toschka.

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ABB sequential turbocharging system



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Engines

Wärtsilä secures ferry and cruiseship contracts

Wärtsilä revealed it would be supplying engines and other systems for two vessels in separate deals announced in November.

A new luxury ferry currently being built for Finnish operator Viking Lines, currently under construction at the Xiamen Shipbuilding Industry yard in China, will be powered and propelled by six Wärtsilä 31DF engines. It will mark the first time in marine application that the 31DF, billed as the world's most efficient four-stroke diesel engine, will be run primarily on LNG. The contract also includes an option for a second vessel.

The total package includes Wärtsilä's LNGPac fuel storage system, a Compact Silencer System, bow thrusters and ballast water management system. Also included is the Nicos Platinum integrated navigation system, which will make it possible to navigate and control the vessel from several onboard positions.

Wärtsilä Marine Solutions president Roger Holm says the project builds upon the relationship with Viking established by the 2013-built ro-pax *Viking Grace*, which was similarly powered by dual-fuel engines. The as-yet-unnamed new vessel will enter service in early 2021, operating between Turku, Finland and Stockholm, Norway.

There was further news from the Finnish technology group a few days later when it said it would be supplying engines and exhaust gas cleaning systems for a 104m exploration cruise ship being built for Miami-based operator SunStone Ships.

The order was placed via Ulstein Design and Solutions, who have been contracted to provide the design and equipment package to the builders,

China Merchants Heavy Industry (Jiangsu) Co. It includes two six-cylinder Wärtsilä 20 engines fitted with the Wärtsilä NOR selective catalytic reduction system, and a further two eight-cylinder engines.

The contract includes the option for a further nine vessels. The Wärtsilä equipment will be delivered to the yard later this month.

www.wartsila.com

Engines

MAN DF engine earns type approval

MAN Diesel & Turbo's dual-fuel MAN L23/30DF engine, which has already secured orders, successfully passed Type Approval Tests (TAT) following testing in front of representatives for the leading class societies at CSSC Marine Power test centre in Zhenjiang, China, in November.

During the TAT, the test engine demonstrated an output of 125 kW per cylinder, at a nominal speed of 720/750rpm. Also tested were the engine's alarm and safety system, dual-fuel safety concept, load-step performance and components. The L23/30DF was also fully compliant with IMO Tier III NOx requirements in gas mode without after-treatment.

The new unit is based on the conventional fuel-oil MAN L23/30H engine originally launched in 1965, albeit much evolved since. Like its predecessor, which was known for its robustness and reliability, the L23/30DF has been developed for cost efficiency and features a simplified fuel injection system with fewer parts. MAN says the engine can run for 36,000 hours between overhauls.

Wärtsilä will supply the engines, navigation and other systems to Viking Line's new ferry



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Finn Fjeldhøj, head of MAN Diesel & Turbo's small-bore, four-stroke department, says: "The L23/30DF covers a power range of 625 – 1,200kW, which makes it particularly attractive for such ocean-going vessels as bulkers of most sizes, general cargo ships, chemical tankers, and smaller LNG-carriers, as well as ships operating in ports and near the coast."

Baltic bulker operator ESL Shipping has placed an order for six L23/30DF gensets for two 25,000dwt cargo carriers currently under construction in China. www.mandieselturbo.com

Assisted propulsion

BMT report highlights Oceanfoil wingsail benefits

Wingsail technology developed by Oceanfoil could offer an average of 14% in fuel and emission savings, according to a report published in December by engineering firm BMT.

BMT's study looked at the year-long performance of four biplane wingsails fitted to a 50,000dwt Panamax vessel operating in the north Atlantic. This consisted of two forward wingsails with drive wings, each 17m high and with an area of 95m², and the two aft biplane wingsails, also with two drive wings, measuring 19m high and with an area of 107m². The total drive wing area is 808m².

The study assessed the thrust benefits for all possible wind angles, using the average (described by BMT as a "conservative" estimate) to define the Oceanfoil wingsail thrust at a given wind and ship speed. Extrapolating from this data, BMT projects that if the vessel were operating at, or near its Continuous Service Rating (CSR), fuel savings of 13% would be possible for worldwide operations.

Chris Moray, Oceanfoil's managing director, says: "For a mid-sized tanker like the one used for the BMT report, this would lead to savings of at least up to US \$50,000 per year."

Ian Jackson, principal naval engineer for BMT Defence Services, comments: "These results reveal a considerable potential for wingsails, and represent an important step in the process towards wingsail technology improving energy consumption for several vessel types over the coming years."

Oceanfoil says it is now in discussions with Lloyd's Register about a solution to the additional visibility and watchkeeping capabilities that will be needed to ensure the wingsails would be fully compliant with SOLAS and COLREG requirements.

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It's the right time for LNG shipping development

Hudong-Zhonghua Shipbuilding Group's winning of a lucrative order from Mitsui OSK Lines confirms China's strength in the construction of LNG ships and its importance in the global LNG ship market

Secured despite fierce international competition, the contract with Mitsui OSK Lines (MOL) will see Hudong-Zhonghua Shipbuilding build four large LNG carriers of 174,000m³ capacity. The total value of the order amounts to more than RMB5 billion (US\$756 million).

Patrick Janssens, Vice President, Global Gas Solutions, ABS, said in an interview with reporters that data indicates that the global consumption of natural gas is growing every year: "As for the development trend of the LNG market, one conclusion is undoubtedly that LNG shipping is about to usher in a bright future. There is no doubt that the use of natural gas in the future will increase greatly. With its rapid development and strength, China's future development of LNG is unlimited. China has many advantages in the field of LNG and there will be tremendous growth in the future market. I firmly believe that

China will become one of the important players in the LNG market."

Chinese LNG potential

In recent years, China's LNG shipping has progressed rapidly and strong impetus for development is seen in both LNG import and transportation. According to the 'Domestic and International Oil and Gas Industry Report', released by CNPC Research Institute of Economics & Technology, China's import of LNG relies mainly on long-term cooperation from Qatar, Australia, Indonesia, Malaysia and Papua New Guinea, while spot trade is mainly from Yemen, Algeria and other countries.

In recent years, changes have taken place in the procurement of LNG in China and private enterprises have joined the international trade of LNG to boost the development of the Chinese LNG industry. On the 1 March 2017, China's ENN Group and Australian supplier

Origin Energy reached a five year LNG framework agreement, formally marking the beginning of the first privately-run natural gas import project in China. In addition, the Jiangsu Qidong LNG receiving station built by Xinjiang Guanghui New Energy Ltd is expected to go into operation in the near future with gas imports being negotiated from countries including Malaysia, Qatar and the United States.

The development of the LNG procurement business in China has directly stimulated the LNG shipping market. At present, the enterprises in China engaged in LNG transportation include China LNG Shipping (Holdings) Limited (a joint venture from COSCO Shipping Tanker (Dalian) Co Ltd and China Merchants Energy Shipping Co Ltd) and LNG Shipping companies established as joint ventures from China Shipping Development Co Ltd and China National Petroleum Corporation (CNPC),

China's first small LNG carrier, operated by CNOOC





The first waterborne LNG filling station 'Seaport Star 01' in China

China Petrochemical Corporation (Sinopec) and Mitsui OSK Lines (MOL) respectively. According to the statistics, during the '12th Five-Year Plan' period (2011–2015) China has built 9 LNG receiving stations, which increased the annual LNG receiving capacity by 27.7 million tons, and with 12 LNG receiving stations now built, the LNG receiving capacity has reached 43.8 million tons annually. There are also 13 LNG filling stations for ships.

Promoting shipping development

In view of the natural gas development, China has introduced many relevant policies in recent years. In November 2014, the general office of the State Council issued a notice on the circulation of 'Action Plan for Energy Development Strategy (2014–2020)', which clearly stated the intention to increase the proportion of natural gas consumption to reach more than 10%. In May 2015, the State Council issued and Premier Li Keqiang signed a document entitled 'Made in China 2025' with the aim to promote the comprehensive implementation and deployment of strategy for future manufacturing. This document made it clear that the international competitiveness of high technology vessels such as LNG carriers will be comprehensively enhanced. In the '13th Five-Year Plan' (2016–2020) for natural gas development, it is specified that comprehensive consideration will be given to the LNG resource supply and ship filling demand in order to plan for the layout of LNG terminals for refueling stations so as to boost the promotion of marine LNG fuel deployment. It is also intended to pilot LNG in river and sea transportations and to have more than 200 ship refueling stations

by 2020. In the document 'Regulations on Fair Access to the Oil and Gas Pipeline Network Facility (trial)', access to the pipelines and associated facilities is outlined, including terminals, loading and unloading facilities, LNG receiving stations, natural gas liquefaction facilities and compression, oil storage and gas storage facilities.

Many favourable policies help to provide a good policy environment for the development of China's LNG shipping. In his speech at China LNG & Gas International Summit & Exhibition 2017, Hu Weiping, president of China Overseas Development Association, said: "In recent years, as environmental protection requirements have become more stringent and the market demand continues to grow, the LNG carrier market will see more opportunities. In 2014, 25% of LNG carriers have dual-fuel engines in use. In the future, natural gas-powered LNG carriers will gradually become the new favourites for LNG transportation. With a number of projects currently under construction coming into operation in 2020, more than 65 LNG carriers will have to be customised for the shipping market."

Bright future

Chinese domestic LNG imports reached 7.8 million tons in the first quarter of 2017, a substantial increase of 30% over the same period last year, according to the statistics. Industry experts believe that, in 2017, China's LNG imports will continue to maintain rapid growth.

Hu Weiping pointed out that, by the end of the '13th Five-Year Plan' period, the total consumption of natural gas in China is expected to reach 360 billion cubic metres. By 2020, China's own conventional natural

gas production will be around 180 billion cubic metres per year and LNG import capacity will be around 80 billion cubic metres per year. It is also estimated that by 2020 there will be demand for around 60 LNG carriers for LNG transportation. Moreover, according to a prediction based on the relevant data, China will build more than 1,000 new LNG-powered ships each year in the future. At present, China has a total of more than 40,000 ships suitable to be converted to LNG-powered or dual-powered vessels, so the market has great potential.

As for the future development of China's LNG shipping market, Hu Weiping gave some suggestions. Firstly, he stressed that attention should be focused on the impact of new markets and new projects on LNG shipping. For example, during the 'Belt and Road Summit', PetroChina announced that it would sign a contract worth US\$20 billion to increase its imports of crude oil and natural gas including from the United States. Sinopec is expected to increase its overseas investment to an amount in excess of US\$30 billion.

Secondly, driven by innovation in shipbuilding and transportation, research and development should be actively promoted for new types of carriers and modes of transport such as LNG icebreakers, floating LNG production, storage and offloading facilities (FLNG), floating storage and regasification units (FSRU) and other high-tech ships.

Thirdly, keeping the demanding characteristics of domestic coastal and inland river small LNG boats in mind, the important role of small and medium sized LNG boats and LNG-powered vessels in LNG transportation should be explored in terms of their contributions to the development of China's 'Green Yangtze River Economic Belt'.

Fourthly, with respect to the implementation of the 'Regulations on Fair Access to the Oil and Gas Pipeline Network Facility (trial)' in addition to good cooperation with third-party receiving stations, one should understand international LNG supply resources and shipping arrangements including coordination in terms of the window period, LNG spot resources, LNG transportations and such like. **NA**

Meeting the Challenge

When IMO agreed to the introduction of the EEDI it set clearly defined reductions of CO₂ emissions for newly constructed ships. But how can CO₂ be reduced using developing technologies? Ian Adams considers the options

The Energy Efficiency Design Index (EEDI) established a baseline for CO₂ emissions from vessels in terms of grams of CO₂ per tonne (of cargo) per nautical mile. The EEDI is being phased in gradually. By the time Phase 3 kicks in from 2025 onwards, the requirement is a reduction of 30% against baseline.

So now the shipping industry has emission reduction targets, how will it achieve them? Can this, as the main marine engine builders suggest, be achieved with the advances made in new engine, turbocharger and propeller designs? Are coating suppliers also able to contribute? Do we simply switch fuel?

Engine Improvements

Most of the two-stroke engines now being installed are long stroke engines with a higher power to weight ratio, which increases propulsion efficiency. To improve the efficiency of an engine manufacturers will seek to improve the ratio of the maximum pressure i.e. the firing pressure and the mean effective pressure. The greater the ratio, the higher the engine efficiency is and the lower the Specific Fuel Oil Consumption (SFOC).

MAN Diesel & Turbo says “With the constraints given by the engine design itself – mainly how high the maximum acceptable pressure inside the cylinder is (the most important parameter) when designing engine structures, bearings, combustion chamber components, and how high the maximum acceptable power (crankshaft design) is – the efficiency of a modern two-stroke main engine and a modern four-stroke auxiliary engine is in fact close to the maximum theoretical efficiency. The efficiency of both engine types is approx. 50%, and further improvement will require significant design efforts, especially when ever-tighter emission legislation has to be fulfilled.”

But further improvements can be made says MAN Diesel & Turbo: “Since we are very close to what is theoretically possible for high-performing two- and four-stroke engines, the efficiency gain has been limited



Record breaker: the Wärtsilä 31

to 1-2% for the two-stroke engine and somewhat more for the four-stroke engine. However, it is important to note that with the ultra-long-stroke G-type engine design, directly-driven larger-diameter propellers can be fitted to ships and, thereby, form the basis for a significant improvement of the overall ship propulsion efficiency. For certain ship types, this improvement of the propulsion efficiency combined with an improved ship design has resulted in up to 20-25% reductions of CO₂ emissions per tonne-mile.”

Significant advances have been made with the four-stroke engine too. According to Patrik Wägar, Product Director, Medium Bore Engines at Wärtsilä Marine Solutions: “With the market introduction of our latest engine type the Wärtsilä 31, the Guinness World record for four-stroke engines was broken reaching efficiency over 50% on the output shaft.”

“The Wärtsilä 31 incorporates technologies such as electronic fuel injection, 2-stage turbo-charging, hydraulic valve actuation, a new generation Control

and Automation System the UNIC 2 and a more robust base design to withstand higher pressures and increase thermal loading.”

Wägar furthers “Looking back, we have improved efficiency by approximately 1% every three and a half years, so 10% over 35 years. With the Wärtsilä 31 a big leap was achieved with efficiency improvement of 1.5 – 4% units depending on fuel type and load range. With the release of a new platform, the potential is built in for upgrades and further efficiency improvement. The limits have been pushed forward. During the next 5-20 years we will see several design upgrades both in terms of improved efficiency, increased output and reduced emissions.”

In all types of engine there are efficiency gains to be made mechanically. By improving the lubrication and the materials of all engine parts subjected to friction further improvements in the overall efficiency of the engine can be made. The predominant area for frictional losses is the piston ring package. Therefore, manufacturers have put a great deal of effort into reducing

this loss. Bearings are another source of friction and again material and lubrication improvements contribute to a reduction in losses and therefore improved efficiency.

Another way that has been proven to improve efficiency is the switch from mechanical control of engines using camshafts to electronic control. Electronic controllers can monitor and adjust for more parameters during the operation of the engine.

Electronically controlled turbocharging also has a part to play in improving a ship's overall efficiency. By having a system that adjusts to the operating condition of the engine manufacturers have been able to reduce the SFOC by up to 3%.

Efficiency gain: 5-8%

Waste Heat Recovery

As the in-engine gains are becoming smaller further improvements are being found elsewhere within the ship's systems. MAN Diesel & Turbo says: "Although small, we do expect that we will continue to see improvements in engine efficiency. However, the big gains in CO₂ emissions reduction are expected to come from improved synergies between the engine and a waste heat recovery system, from intelligent utilisation of hybrid solutions (potentially batteries)."

The engine builder continues: "In combination with a waste heat recovery system, the efficiency of the prime mover will increase to approximately 60% from the approximately 50% today for a standalone engine."

Efficiency gain: 10%

Computer Aided Design

Wärtsilä's Wägar, meanwhile, adds that the new developments in computer assisted engineering techniques can help to improve the overall efficiency of the engine. "Through simulations and virtual validation techniques we get a good view of the potential in theory, and today simulations have been improved that much that we are surprisingly close to what we see in reality. We do not want to revwear numbers at this stage, but there is clear potential. We are confident to keep a pace of 1% improvement every 3.5 years, perhaps even escalate the progress."

Efficiency gain: 2-5%

Hull Coatings

Another way of improving a ship's efficiency is the hull coating. Over at Hempel they have been developing Hempaguard. Hempel claim "Hempaguard can deliver six per cent fuel savings across the entire docking interval compared with best-in-class antifouling solutions. Since its inception in 2013, Hempaguard has been very well received by ship owners and operators around the world with over 800 full vessel applications. This is thanks to its unique technology – the patented Actiguard technology."

"The only hull coating to combine the low surface friction of silicone with efficient fouling preventing biocides in a single coat, Hempaguard achieves outstanding resistance to fouling, even during idle periods of up to 120 days. Hempaguard goes one step further in delivering efficient operations as it retains its effectiveness when switching between slow and normal steaming offering unrivalled flexibility in fleet utilisation.

"Hempel also recently launched a new antifouling coating range, the Globic 9500 series. These are two premium antifouling coatings – Globic 9500M and Globic 9500S – which offer customers a potential 2.5 percent reduction in speed loss, equating to significant fuel savings and lower CO₂ emissions. This significantly improves the operational efficiency of a vessel and minimises the operator's environmental footprint.

"This new range of antifoulings have been specifically designed for new buildings and dry-dockings. Globic 9500M (M for maintenance) protects against slime as well as soft and hard fouling. Globic 9500S (S for static) protects against hard fouling even during extended outfitting periods.

"Interestingly these two coatings are built on nano acrylate technology that provides full and immediate antifouling protection the moment the vessel is placed in the water. It encompasses a fine polishing control mechanism to bring the integral biocides to the surface at a steady and stable rate."

"Together these two coatings deliver unparalleled protection and are the next step in high performing antifouling protection offering customers improved operational efficiency, flexibility and a high return on investment.

Hempel continued: "We also believe in offering the right services to further assist our customers achieve operational efficiency. For example, we have a hull performance management team that works with customers to accurately measure performance data of the hull. This determines the environmental efficiency and performance of the vessel, and subsequently the return on investment of the hull coating. Utilising this information correctly and determining exactly how fuel savings are being achieved, we can offer solutions and discuss making adjustments if the performance of the vessel drops."

Efficiency gain: 6%

Switching Fuel

A great deal has been made about Liquefied Natural Gas (LNG) being the panacea for ships' fuel. However, the fact that LNG is predominantly methane which is a greenhouse gas (GHG) 28 times more potent than CO₂ is usually ignored. Methane slip through the entire supply chain not to mention through the engine has the potential to negate any benefits LNG may offer. There are better alternative fuels such as methanol which do not have the hazards associated with LNG.

Efficiency gain: 0-20%

Conclusion

So, as a very simplistic analysis the possible accumulated gains are 23-29% improved efficiency before we consider a switch of fuel. Both MAN Diesel & Turbo and Wärtsilä Marine Solutions are continuing to develop engines with greater efficiency. By combining these engines with other technologies, such as waste heat recovery to generate electricity, and advanced coating technology, the future emissions targets appear achievable. **NA**

About the Author

Ian Adams is Managing Director of IMA Marine, a consultancy specialising in bunker fuels. Services offered include advising on purchasing policy, training, and provision of expert witness. Adams was the secretary general/CEO of the International Bunker Industry Association (IBIA) between 2001-11. He holds the Cardiff University Bond Solon Civil Expert Certificate.

Fast sailing in ice– the new goal of model studies

Maintaining a fast, efficient year-round shipping line in the Russian Arctic for large-size vessels demands adequate ice-going capabilities, say the Krylov Centre’s A.A. Dobrodeev and K.E. Sazonov

Russia is striving to expand commercial development of Arctic resources, and in this context it is becoming important to ensure a year-round shipment of hydrocarbons produced in the Arctic not only to the Western destinations, but also to the Pacific Rim countries like China, Korea and Japan. From experience we know that historically the progress of ice technologies has been driven not only by state-of-the-art research, but also by long-term goals and strategies of the nation [1].

In the past the primary goal of transportation in ice-infested waters was to provide life support services to small population centres in the northern regions, so-called the ‘northern supply haul’, which was done by relatively small-size ice class ships. The main task of these vessels was to deliver cargoes to Arctic harbours. Economic considerations were of secondary importance.

Commercialisation of the Arctic and a shift to year-round freight transportation from the Arctic (not only to traditional Europe and US destinations, but primarily to the Pacific Rim countries [2]) has given an impetus to the development of new ice-going vessels. Table 1 gives some data regarding the covered distances and time scales of cargo shipments from Murmansk to the main Pacific ports, which demonstrates the attractiveness of these logistic solutions.

Arctic cargo shipments to the Far East have to be economically competitive with the itinerary around Eurasia. Competitive advantages can be achieved if average speeds of heavy-tonnage vessels in ice-infested



Fig. 1: Model studies for operation in narrow channel behind icebreaker

waters are increased to 12-14knots. With this purpose in mind Russia is building a new series of 60MW icebreakers, including a super-powerful icebreaker of a new generation [3] as well as developing large-size cargo vessels of high ice classes. One example of the latter is the LNG tanker *Christophe de Margerie*. Such vessels, however, are constructed based on experience and rules inherited from previous generations of ice-going ships, which had much smaller dimensions and operated in ice at relatively slow speeds (as a rule 5-6knots) [4].

The need to attain higher speeds in ice calls for substantial changes in our approaches to design of icebreakers and heavy-tonnage ice

class vessels. Until recently fast ship speeds in ice have not been considered as an issue of primary importance. Further studies are needed to gain a deeper insight into ice-going performance, strength aspects, ice/propeller interaction and icebreaker/ship coordination to enable operation at higher speeds. All these issues have to be resolved in the immediate future because transportation systems for speedy sailing in ice are already in the making. Solutions to many of the above problems can be found from ice basin experiments. Some results obtained in the Ice Basin of Krylov State Research Centre during research studies on fast-speed operation of large-size vessels in ice are discussed below.

A heavy-tonnage vessel can only operate at high speeds in ice features of more than 1.5m thickness with the assistance of a powerful icebreaker. Experiments conducted in the ice basin were intended to investigate the operation of an icebreaker making a navigable channel in ice as well as operation of a large-size vessel sailing behind in the ice channel. Two options of advanced nuclear

Table 1: Cargo shipment distances and time scales

From Murmansk nm/days	via Suez	via Northern Sea Route
Kobe (Japan)	12291/37.1	6010/18.1
Busan (Korea)	12266/35	6097/18.4
Ningbo (China)	11848/35.8	6577/19.9

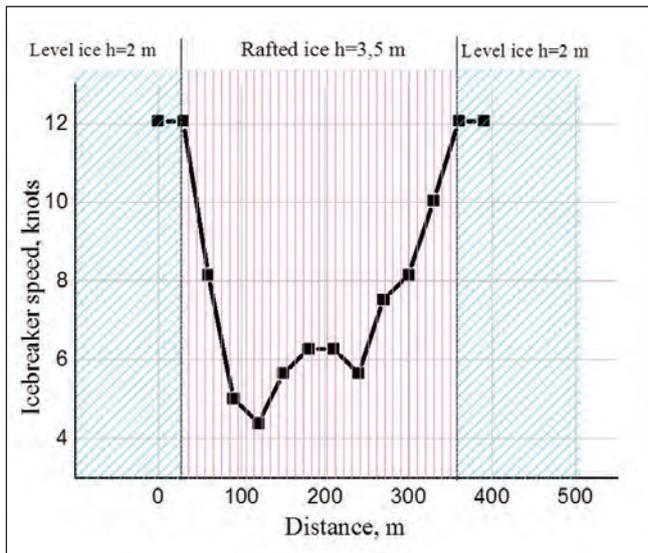


Fig. 2a: Rafted ice. Thickness - 3.5 m

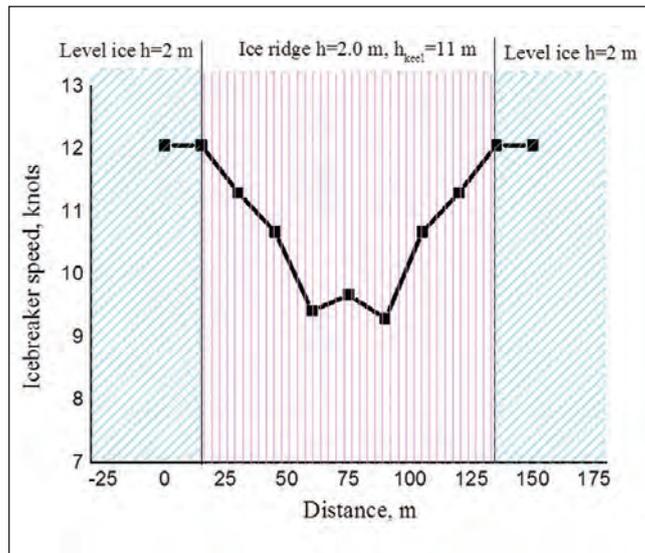


Fig. 2b: Ice ridges. Consolidated layer thickness - 2.0m, keel depth - 11.0m, width - 100m

icebreakers were considered in these studies: a 60 MW icebreaker of new *Arktika* type and a 120MW icebreaker. A heavy-tonnage vessel model of the *Christophe de Margerie* type was also chosen.

In the icebreaker model tests the main focus of attention was on the icebreaker speed modes under various ice conditions as

well as possible speed variations in case of sudden changes in ice situation (ice ridges, rafted ice, etc.). Self-propelled model tests in continuous level ice have revealed that the icebreaker is able to make a channel in ice of 1.5-2m thickness at a speed of 10-12knots. Thus, there are icebreaker enablers of sufficient capacity to implement a future

transport system for speedy navigation in ice-covered waters.

The experimental data of Fig. 2a show what happens with the speed of the 120MW icebreaker running into ice features in a continuous level ice field: rafted ice of 3.5m thickness and about 400m length; and ice ridges of a 2.0m

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Heading	Ice conditions	Model test data	Operational requirement
Ahead	Channel in 1.4 m thick ice	9.2knots	12 knots
Ahead	Channel 2.0 m thick ice	7.2knots	12 knots

consolidated layer, keel depth 5.0 and 11.0 metres, and width 50 and 100 metres.

Fig. 2b shows how the icebreaker speed changes when the ship meets with an ice ridge of 11m keel. When the leading icebreaker passed a ridge of smaller depth, the speed loss was not more than 1 knot; therefore, the test data is not shown in this case. Analysis of the experimental data provided in Figs 2a and 2b suggests that the 120MW icebreaker demonstrates good inertial performance to overcome significant ice features without stopping.

Speed modes of a large-size LNG tanker sailing in the channel made by the 120MW icebreaker were also investigated. The results of these experiments are given in Table 2.

The obtained results indicate that the maximum speeds attainable by the LNG tanker under study in a fresh channel behind the 120MW icebreaker in 2.0m-thick ice is 7.2knots ahead, and 9.2knots ahead in 1.4m-thick ice. Behind the 60MW icebreaker the tanker speeds are even slower because the channel made by this icebreaker is narrower and the tanker has to widen it.

Unique experiments under simulated ice compressions show that under ice loads at ice compressions of 2.0 to 3.0 (severe) and ice thickness of 2.0m, an Arctic LNG tanker drifts off the course in the direction of ice compressions and reaches the fast ice edge. The ship speed in the ice channel drops because her entire hull length is in contact with the channel edges. In relatively thin ice, as well as at ice compressions less than 2.0 (mild), the ship may advance steadily under partial contact of her sides with the edges. However in this case the tanker sailing behind is subject to compression around the entire length of the hull, which may cause significant speed loss and jamming in ice. Therefore, nuclear icebreakers have to use special tactics to avoid undesirable effects of ice compressions on a large-size LNG tanker in an ice channel. Krylov State Research Centre develops and

verifies such tactical methods in the Ice Basin.

Another important factor is interaction of propellers with thick ice at high ship speeds. Higher speeds of ship operation in ice are expected to cause the most serious problems for propeller and rudder systems. These problems may be different for independently sailing vessels and vessels following an icebreaker in an ice channel. Independent sailing in ice at 12 to 14 knots will require a 1.5-fold increase in the available horsepower even for the stern-first mode. The propeller diameter will have to be increased in this case, which is not always possible because of draught and design constraints, and/or the propeller speed will have to be increased. In any case ice loads on the propeller will grow. The most realistic solution (though quite a difficult one from the standpoint of general ship design) would be to increase the number of ship engines and propellers.

On the other hand, practically all calculation methods today assume that the worst case scenario is ice milling. As shown in the studies of A.V. Andryushin [5], if the speed in ice is increased at the same propeller pitch, the blade angle of attack at ice milling (ice cutting angle) should inevitably decrease, and a blade of zero attack angle may fall flat and bend under ice action instead of cutting ice. Also, the ice-milling design condition should be complemented with calculations of shock effects on blades inflicted by ice pieces or collisions with ice edges in the channel behind the icebreaker. The latter effects are most important for twin- and multi-shaft vessels, and are applicable to all vessels of high ice classes. The probability of such interactions is even higher for vessels equipped with two or more propulsion pods. Reliability of thrusters should be appraised not only in terms of blade strength but also based on the overall robustness of podded thruster units that should be able to withstand ice impacts at fast speeds.

The main conclusion of the above experimental studies is that hull forms of

Table 2: Speeds of large-size LNG tanker in ice channel.

heavy-tonnage vessels should be designed specifically for speedy operation in ice channels behind icebreakers. The heavy-tonnage vessels designed for independent sailing in ice cannot maintain the required speed level in ice channels to support fast operation of the entire marine transportation system. *NA*

About the authors

Dobrodeev Aleksey Alekseevich PhD is head of the ice researching section at the ice model basin of Krylov State Research Centre. e-mail: A_Dobrodeev@ksrc.ru

Sazonov Kirill Evgenievich, Doctor of Technical Sciences, is Head of Laboratory at the Krylov State Research Centre. e-mail: kirsaz@rambler.ru

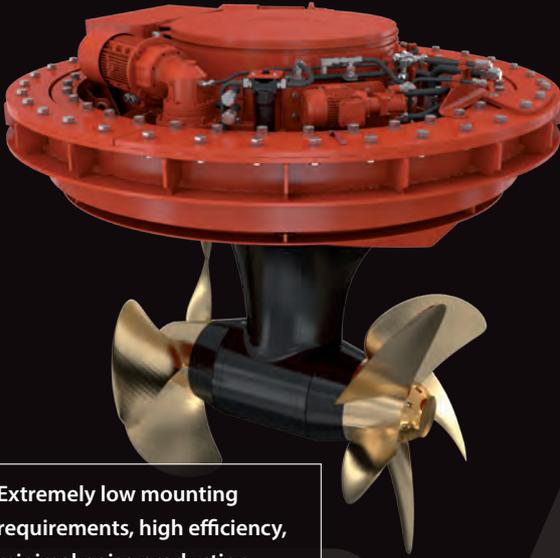
*Krylov State Research Centre,
196158, Russian Federation, St.Petersburg,
44, Moskovskoe shosse
Tel: +7 (812) 386-69-78*

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System analysis for design-side innovation to reduce a ship's carbon footprint

HydroComp's technical director Don MacPherson explains the steps involved in the hullform optimisation for a LNG-fuelled Ro-pax project that forms part of the EU-backed Poseidon Med II initiative

It is fair to say that the production of greenhouse gases, particularly CO₂, has become a major design driver for naval architects. Regulation has mandated limitation of emissions, and we are also seeing owners voluntarily taking steps to reduce harmful CO₂ and to reduce their ship's carbon footprint.

Recently, the owners of Blue Star Ferries put forth a challenge to Greek engineering company NAP Engineering P.A. and their subcontractors US-based HydroComp Inc. to do just that. The project was part of the EU co-funded Poseidon Med II Deliverable 14.4, which called for a compact LNG-fuelled Ro-pax ferry design. The vessel was limited to 145m length overall and was to carry 1,400 passengers and provide for 1,000 lane-meters of automobile and truck capacity. Additionally, the vessel was to comply with SOLAS, 'Safe Return to Port', and IGF Code Rules and Regulations. The design has already received Approval in Principle (AIP) from Lloyds Register.

A 'carbon footprint' design objective

The measure of carbon footprint reduction was defined as the CO₂ emissions before-and-after hull form design optimisations and analysis of performance with different main engine options. In essence the study was to determine the overall total-voyage reduction in CO₂ by optimisation of a given initial hull geometry and the use of a dual-fuel engine versus a conventional diesel engine – all as part of early-stage initial design.

Credible prediction of CO₂ for the mission therefore required the following analytical capabilities for a complete hydrodynamic propulsion system simulation:

- Prediction of bare hull resistance plus added resistances, such as appendages, wind, and seas
- A Hull-Propulsor-Driveline-Engine system simulation model that could

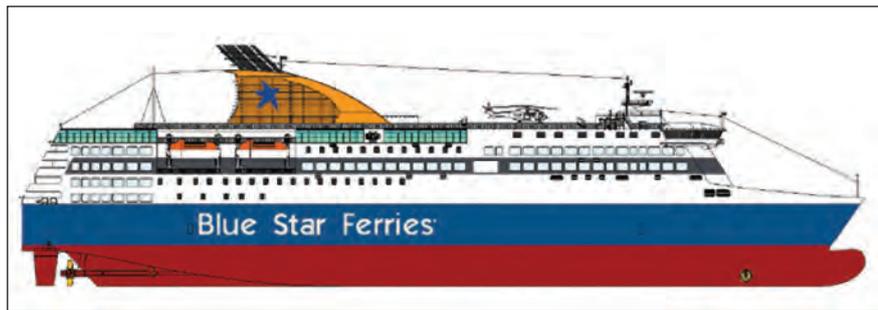


Figure 1: Profile schematic of the initial design concept

Slow	8knots	7.1nm	0.9 hours	MDO
Moderate	18knots	6.7nm	0.4 hours	MDO
Cruise	22knots	340.8nm	15.5 hours	MDO or LNG

- provide the equilibrium thrust and power requirements at each speed
- Controllable-pitch performance in a constant RPM condition (with RPM correction for low pitch operation)
- Accurate prediction of engine fuel rate for both single- and dual-fuel configurations
- Definition of multiple fuel carbon content for further prediction of CO₂
- Duty-profile operating modes analysis to determine the unique propulsion and CO₂ characteristics for each mode

Further, hull form optimisation at early-stage design called for a bare hull prediction method that allowed for local modification of hull form. HydroComp's NavCad software (Premium Edition) was employed to provide this full simulation framework.

Duty-profile of the Ro-pax

The client specified a round-trip voyage of multiple segments, with three voyages per week and an annual service of 48 weeks. The multiple transits and movements were

collected into three principal operating 'modes' representing a one-way voyage of 354.6 nautical miles (as shown above).

During early-stage design, use of 'parametric' (or [1D]) prediction methods is very popular due to their limited data requirements and empirical foundation. Some 40 different predictions were available in NavCad that could be applied to the prediction of bare hull drag (only a few of which would be suitable for any particular vessel, of course). Correlation to prior trial or model test data could be applied if such test data were available. However, the one thing that makes these methods quantitatively strong and well-behaved – their characterisation of the immersed volume with discrete 'parameters' and their statistical extraction of resistance data from empirical tests – also makes them less effective as a tool for qualitative optimisation of local hull shape. This requires a method with greater definition of the hull form geometry which can be manipulated and evaluated as part of an optimisation study.

Some consideration was given to the use of CFD (a [3D] analysis) for the hull form resistance prediction and optimisation, and then to connect the CFD output back into NavCad for the total propulsion system simulation of engine load, fuel consumption, and CO₂ production for the full operating modes duty profile. However, given the early stage of the design – where final hull geometry was still in question – it was determined that the cost, time, and resources of [3D] CFD did not match the order of the problem at that time.

Fortunately, NavCad provided an alternative method of higher order for resistance prediction using its Analytical Distributed Volume Method (ADVM). Neither describing the immersed volume by parameters [1D] nor by its full surface envelope [3D], the ADVM is a [2D] method using the longitudinal distribution of the ship's immersed volume (e.g., sectional area curve, immersion center of the section area, and beam distribution). This provides a much more detailed definition of the immersed volume and provides the qualitative means to investigate how changes in local geometry will affect ship resistance (the distributions for the initial Ro-pax hull form are shown in Figure 2).

Briefly, the ADVM method is based on calculation of the Kelvin wave system of diverging and transverse waves, using a nested integration of the above described longitudinal distribution of the immersed volume. While the basic methodology employed by the ADVM is inviscid, the influence of viscosity on the prediction of the wave-making system is considered with a variety of corrections, such as for hump-hollow oscillations, dynamic trim, and for the proper 'hydrodynamically-effective' length of the hull form to be represented.

A supplemental outcome of the method is the prediction of far-field wave-pattern elevations. This is often used to communicate before-and-after energy savings (by reduction of generated wave height) during hull form optimisation. A sample of an ADVM-generated wave pattern is shown in Figure 3.

The 'whole-ship' resistance is more than just wave-making, of course, so the method also considers scalable viscous properties through a contemporary assessment of frictional drag (using a line based on boundary layer analysis) and form factor.

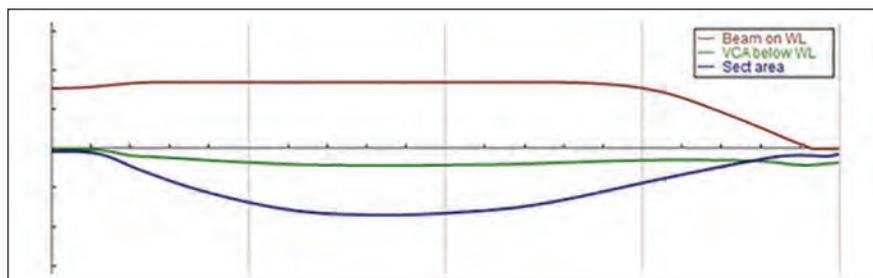


Figure 2: Longitudinal distribution of immersed volume, as represented by beam, sectional area, and center of area immersion

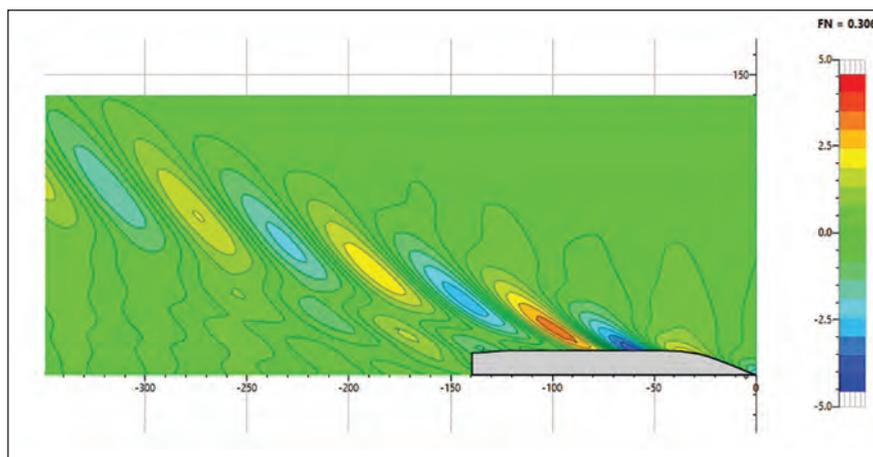


Figure 3: Example wave pattern elevation

	Design FN	CVOL	CP	AB/AX
Ro-pax	0.31	6.0	0.62	0.11
KCS	0.28	6.2	0.66	0.09

That said, the method is not suitable for all vessels – even with the described research and development efforts to properly model and predict all component of total bare hull resistance. For example, the method has shown limitations for ships with substantial buttock flow versus waterline flow, such as for barge forms and very shallow vessels.

Therefore, validation of the ADVM code – or any code, for that matter – is paramount. Such validations can be conducted using a variety of different basis criteria, including model tests or other numerical calculations (such as CFD). Validation against other numerical methods, however, presumes that the calculations have been set up and conducted correctly, and that the methods are suitable for the characteristics of the hull form. Of course, the same can be said for model

testing, but with a critical eye toward the preparation and peer-review of the model test program, suitable model tested hulls can generally be found. The basis for comparison must therefore be public and widely considered as a suitable benchmark for validation of analytical methods. The significant hydrodynamic parameters of the model and its test must also be similar, such as design Froude number, volumetric fineness coefficient, prismatic coefficient, bulb area ratio, and the shape of the sectional area curve.

After an extensive literature search, one benchmark stood out as a suitable proxy for the Ro-pax and a basis for validation of the analytical resistance prediction method. This was the well-known KRISO Container Ship (KCS). A comparison of the principal characteristics of the KCS and the Ro-pax vessel is shown above.

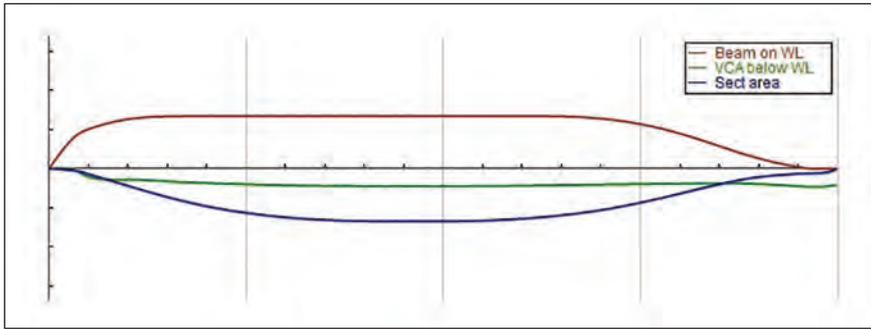


Figure 4: KCS validation model distributions

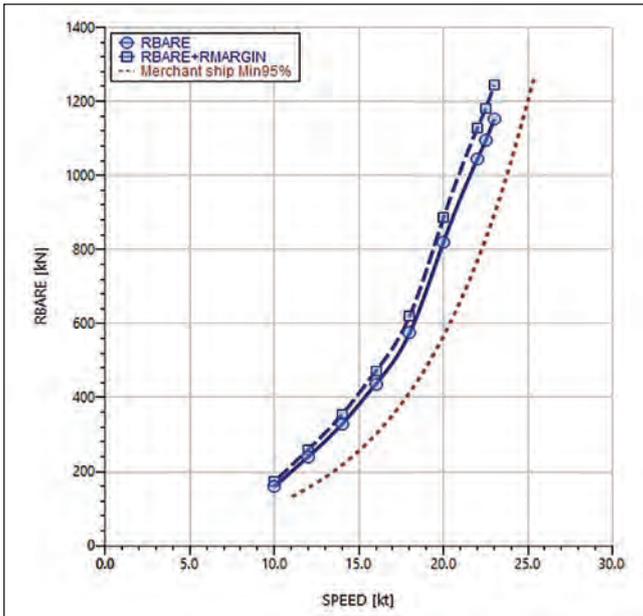


Figure 6 - Ro/Pax initial hull form prediction 'Confidence Plot'

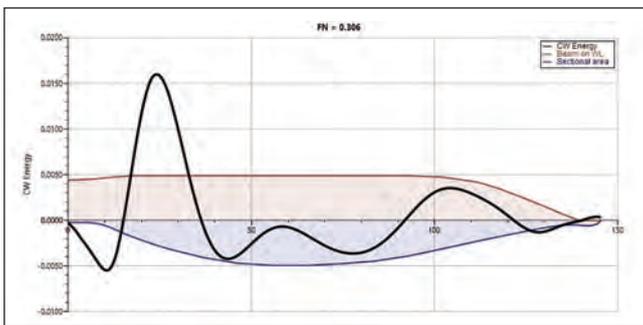


Figure 7: Longitudinal wave source for initial hull

The equivalent longitudinal distribution of the KCS hull is shown in Figure 4. Compare this distribution to the initial Ro-pax hull (in Figure 2), and it is easy to see that the KCS is a suitable validation proxy for the Ro-pax.

Resistance for the KCS model was predicted using the ADVm method and compared to results from the published model test reports. Figure 5 demonstrates the outcome of the validation, which captures very well the resistance curve

shape of the model test, albeit with some small over-prediction of resistance (possibly due to slightly insufficient suppression of hump-hollow oscillation in the method). However, as the prediction was qualitatively faithful to the model test and quantitatively a bit conservative, the ADVm method was deemed a suitable prediction method for the Ro-pax study. (With respect to computational load, the calculation time using the ADVm method was approximately two seconds per ship

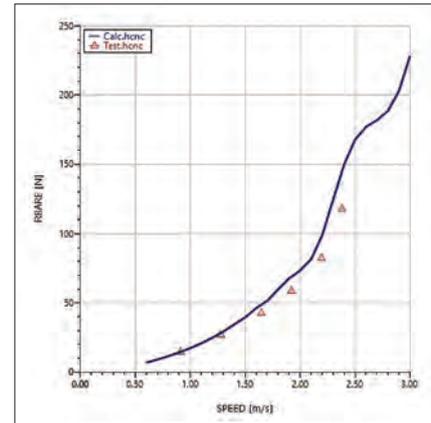


Figure 5: Prediction results for the KCS validation

speed using a typical business-grade laptop computer. The least time found in the literature search for CFD analysis of one speed for the KCS was 1.7 hours using a 24 core cluster. Using these reference computers and methods, calculation efficiency using the [2D] method is some 3000-to-1.)

Hull form modification for drag reduction

Once that the ADVm method was considered suitable for the Ro-pax, the resistance prediction was prepared and compared to a NavCad 'Confidence Plot' (i.e., an 'optimistic lower-limit' design guide) as shown in Figure 6.

The qualitative curve shapes matched the 'lower-limit' confidence line very well, but the magnitude of drag was higher than expected. This suggested to the project investigators that the hull was not optimal. A critical review of the initial hull form was performed to try and identify obvious shape characteristics that might be improved. The inflection of the sectional area curve at the stern was deemed to be a candidate for modification.

An innovative new corollary recently developed within the ADVm framework is the ability to produce a plot of the 'longitudinal wave source'. This provides a visualisation of the position source of the wave-making energy (resistance). As you can see in Figure 7, the region of significant wave-making energy is centered just upstream of the severe inflection in the sectional area curve at the stern.

It will sometimes be necessary to look downstream of any wave source peak for locations that may require attention.

Condition	Initial	Proposed	Change
Fuel	MDO	MDO/LNG	
Total fuel energy	3.10 MJ	2.66 MJ	-14%
Total fuel mass	72.5 t	55.5 t	-23%
Total fuel volume	80.5 m ³	122.2 m ³	+52%
Total CO ₂	31.7 t	20.9 t	-34%

It is the nature of fluid flow that changes in body geometry can affect pressure upstream – and thus wave-making resistance. For example, consider a simple 2D foil (of NACA 16 thickness distribution; Figure 8a). The original thickness was modified at the tail from the

80% chord position aft with an inflection similar to that of the initial Ro-pax hull. You can see in Figure 8b a peak pressure change upstream of the shape change.

This confirmed that the downstream stern inflection was indeed a good candidate for optimisation. A slight

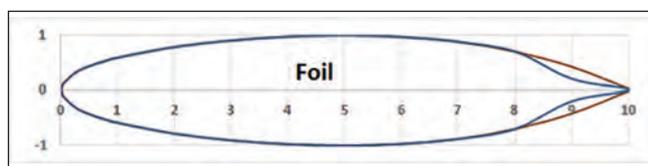


Figure 8a: Foil shape modification

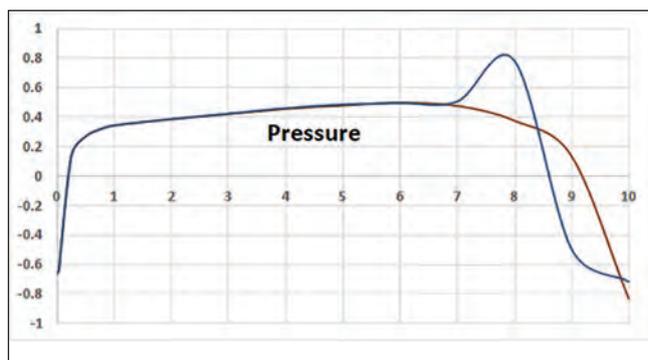
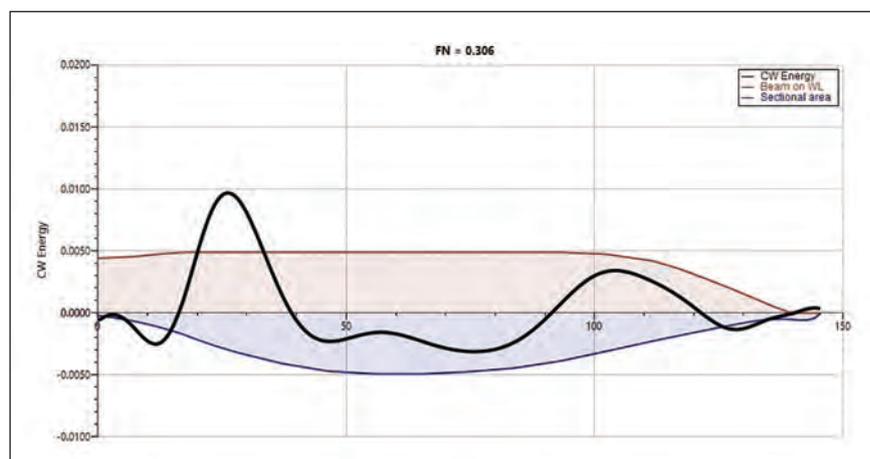


Figure 8b: Corresponding pressure change

Figure 9: Longitudinal wave source for modified hull (with smoothed stern)



modification of the stern to smooth the distribution (making it more flow – friendly, as described in Figure 9) provides a substantial reduction in the generated energy and resistance. Given the major contribution of wave-making to the total drag, the stern modification reduced total bare hull resistance by nearly 10%.

Steady-state propulsion simulation, fuel rate, and CO₂ production

The vessel was initially designed to be powered by a pair of diesel main engines, through a single-stage non-reversing gearbox, to controllable-pitch propellers (CPPs). The mode of CPP operation was specified for constant RPM, with pitch varied to meet the equilibrium thrust requirement.

The propulsion system simulation included prediction of hull-propulsor interaction, the equilibrium pitch (for steady-state thrust matching at each speed and engine RPM), and all corresponding propulsion metrics such as power, efficiency, cavitation, fuel rate, and CO₂ production. Definition of fuel properties (MDO and LNG, in this case) were prescribed by the IMO MEPC 281(70) reference, including density, heating value, and carbon content.

Two competing engine models were specified for the initial and proposed optimised design – one MDO (Wärtsilä 12V46F) and one dual-fuel MDO-LNG (Wärtsilä 12V46DF). The initial versus final design configurations were both evaluated in a duty-profile operating modes analysis in NavCad, where the total fuel use and CO₂ production could be calculated for each mode. Each unique mode operation was defined for engine engagement (such as for idle or compound engine operation), particular fuel type for the mode, and the mode service (transit or towing, for example). The overall comparative performance is shown in the table at the top of the page.

The ship makes 288 of these trips each year (144 round-trip voyages). The optimised vessel with the dual-fuel engine option is therefore projected to reduce its annual CO₂ production by approximately 3,100 tonnes. **NA**

Optimarin looks to guarantee satisfaction

As competition among ballast treatment systems steps up following IMO's green light for implementation last year, the Stavanger-based company is aiming to consolidate its position with a unique offer

Ballast water treatment may not appear the most glamorous area of maritime research and development but for employees at Optimarin it's a way of life. At least that's according to Tore Andersen, CEO at the Norwegian company, who says: "Every single person is working, thinking and dreaming about ballast water treatment."

Like many companies specialising in ballast systems, particularly those without additional revenue streams from other technologies, Optimarin had to wait patiently before IMO's Marine Environment Protection Committee (MEPC) finally agreed the timeline for implementation in July last year. The Optimarin Ballast System (OBS) UV-based process first received IMO type approval in 2009 (further gaining US Coastguard type approval in late 2016) but is only now starting to turn a profit. Including retrofits, around 330 OBS units have been sold, covering all types of vessel.

Yet in many respects the game has only just begun. With more than 60 competing systems, each with varying degrees of IMO or USCG approval, it's likely that only a fraction will prove financially viable. Indeed, only a handful of companies have sold more than more than a hundred systems each. But as orders begin to rise, the onus among manufacturers is shifting towards how best to persuade shipowners of the advantages their system has over that of their competitors, be it through the provision of training for crew or in the form of after-sales care.

To that end, in November Optimarin announced it will become the first company to offer a five-year guarantee for all spare parts and consumables for OBS units installed on vessels, including an onboard check by one of its dedicated technicians at the two-and-a-half year service interval.

Andersen explains that the guarantee was developed partly in response to ABS's survey of shipowners, which revealed only 57% of



Tore Andersen,
CEO, Optimarin

ballast systems are being operated correctly, with the rest being deemed 'inoperable' or 'problematic' (see September 2017's *Naval Architect*). "That's a shame from our point of view," Andersen laments. "We can't sell these things for millions of dollars if we can't guarantee it will work."

Andersen says that unlike some of their rivals, who are onto second or third generation systems, Optimarin are still selling ostensibly the same technology, which has given them the confidence to offer this guarantee. "We believe that if it works in the first year, and if it is maintained as we've said in the operation manual, then it will work further down the line. But it places a challenge on us as it means we have to be in close contact with the owner to make sure the system is working."

Optimarin now has more than 30 dedicated service engineers around the world and spare parts located at five main strategically located shipping hubs. It also has engineering partnerships with Goltens and Zeppelin. As part of the guarantee package each unit will come with two and a half years of spare parts on board. The company also offers a service called Optilink, which allows its technicians to provide online guidance and even update the system's software if necessary.

OBS systems are capable of treating up to 3,000m³ an hour and in some cases have

been installed on tankers of 110,000dwt, although 60,000dwt is generally the upper limit. Theoretically it would be possible to 'double up' and install more than one unit, although Andersen concedes that the additional power requirements needed to run a UV system mean that electrochlorination is the better choice for larger vessels.

He adds that the technology behind the OBS system is not rocket science, but developing awareness among shipowners and crew is a tougher challenge. "There's a filter, valves and a UV chamber. We try to explain to shipowners that they shouldn't think this thing is difficult or dangerous. But how to operate it correctly and what to do when an alarm goes off – that kind of discussion is very important. Do the people on board understand the Ballast Water Management Plan and what kind of restrictions they have on their system?"

"The best illustration is to say that on a mid-size ship that's pumping water at full flow, from the sea into the tank, it's going through a 200-500mm pipe at thousands of cubics per hour. But when you put the system aboard you have to push all the water through 40 micron filters you can hardly see through. If you understand that you realise you cannot just start pumping when it fits your operation. You need to plan ahead." **NA**

Ballast testing critical to Gulf access

Protecting the Persian Gulf from invasive aquatic species has long been an issue for countries bordering the region and the maritime community. Brian Phillips, Managing Director, Chelsea Technologies Group, explains why ballast compliance is essential for continued access to Saudi ports

As a semi-enclosed water body, there is little exchange in the Persian Gulf with the open sea, making it particularly vulnerable to the threat of invasive aquatic species. Regulations were introduced in 2009 to prohibit the exchange of ballast water within the ROPME (Regional Organization for the Protection of the Marine Environment) sea area, bordered by Bahrain, I.R. Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates, complementing a raft of additional regional environmental measures.

Further international protection emerged in 2017 following MEPC 71 in July and the entry into force of the Ballast Water Convention (BWC). Although the BWC came into force on 8 September 2017, the decision to extend the deadline for the retrofitting of existing vessels with BWTS has provided some shipowners with the opportunity to delay compliance with the regulations until further down the line.

The revised BWC introduces two standards for the handling of discharged ballast water to halt the spread of invasive aquatic species. D-1 addresses the ballast water exchange standard and D-2 details the ballast water performance standard using an approved BWTS.

The D-1 standard requires ships to ensure that ballast water is exchanged far away from the coast where coastal organisms will not survive due to different temperatures and salinity. The D-2 standard requires that only ballast water with a concentration of less than 10 viable organisms per cubic metre >50µm in the smallest dimension or less than 10 viable organisms per millilitre between 10-50µm in the smallest dimension can be discharged in ports and coastal waters.

Along with the United States, Saudi Arabia has opted to move ahead with enforcement of ballast water regulations.



Dr Brian Phillips, Managing Director,
Chelsea Technologies Group

This was reinforced by the announcement from the world's largest oil producer, Saudi Aramco, that all vessels calling at its ports will be required to provide a ballast water sample and report. Saudi Aramco is among the highest receivers of ballast water from ships, with over 180 million tonnes of ballast water discharged during cargo operations.

With access to such a huge market at risk, vessel operators and owners must therefore carefully consider both the form and scope of current and future operations to determine how the Convention applies to them, and how they can ensure compliance with minimal impact on operations and profitability. Personnel need to be trained to operate a BWTS and interpret the compliance data, and this crucial requirement cannot be overlooked, given the significant capital shipowners will need to invest in installing an approved BWTS, and the numerous reports of crews reporting concern with performance and accuracy.

Chelsea Technologies Group (CTG) has direct experience of ballast water management and compliance with the high standards demanded by regulators. CTG's FastBallast Compliance Monitoring System was identified by Saudi Aramco's in-house marine biology experts as the most accurate solution in the market for the sampling and testing of ballast water, and will be used to conduct spot checks undertaken by third-party sampling companies.

FastBallast is able to accurately determine the phytoplankton cell density of ballast water to IMO D2 & USCG Discharge Standards (10-50 µm range). I believe it is the only technology that can provide a high degree of accuracy as both an integrated flow-through system and as a portable compliance tool, providing the port state control officer the same level of confidence in the results as with laboratory analysis, in-situ and in a much-reduced timeframe. It is unique in that it can determine cell size, a fundamental requirement in producing an accurate cell count when using fluorescence techniques. Additionally, Global Strategic Alliance Saudi Arabia (GSA), CTG's agent for Saudi Arabia and Bahrain, is working closely with the Saudi Arabian authorities to set FastBallast as the national benchmark for accurate and reliable ballast water sampling.

Saudi Aramco is prioritising environmental protection and has set high standards in driving change ahead of regulations. With planned investment in port infrastructure of US\$30 billion, the Kingdom will continue to be a huge market for shipowners. To carry on accessing this important market vessel crews must have confidence in the integrity of the BWTS they have invested in, and the knowledge to spot any issues with the compliance data. Failure to do so will prolong damage to the environment and will impact brand and reputation. **NA**

Aqua-tools champions ATP tests for ballast sampling

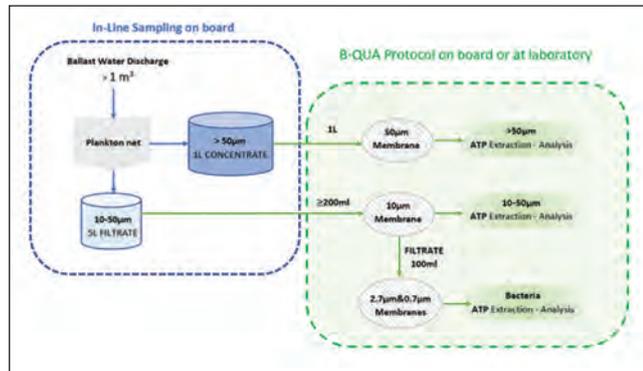
The French company says its method for detecting adenosine triphosphate is the only sure-fire method for ensuring treated water is compliant

Following the entry into force of the Ballast Water Convention in September 2017, attention is turning towards how to effectively monitor the efficacy of the treatment systems being installed onto vessels so that discharged water is meeting the standards specified by IMO.

Under IMO's D-2 regulation, treated ballast water should contain less than 10 viable planktonic organisms per cubic metre greater or equal to 50µm in size and the same number for those of 10-50µm. Toxic and infectious types of bacteria less than 10µm such as some types of *vibrio chlorea*, *E. coli* and *intestinal Enterococci* must also be tested for.

The most accurate results for verifying these organism numbers are gained through detailed laboratory analysis but this is obviously time consuming and requires skilled technicians. A more realistic method for enabling both crew and port state control inspectors to conduct rapid but effective sampling of treated ballast water with minimal training is through indicative methods, which detect chemical indicators to assess the biomass and viability of organisms in the water. IMO has listed a number of accepted indicative techniques including testing for chlorophyll fluorescence activity (CFA), adenosine triphosphate (ATP), fluorescein diacetate (FDA), pressure measure and bacterial fluorometry.

French company Aqua-tools, which specialises in water microbiological testing for the marine, industrial and health sectors, has (in partnership with Swiss company SGS) developed the B-Qua test kit, which analyses ballast water for the presence of ATP based on the principle of bioluminescence. B-Qua, which is suitable for both onboard sampling and tests made by port state control inspectors, involves drawing a cubic metre of ballast water (typically using a plankton net) and taking two samples: the first (one litre) sample is



Using B-Qua's system treated water is passed through filters before ATP extraction

passed through a membrane which filters out organisms >50µm, while the second (200ml) sample is passed through a 10µm membrane. Half of this second sample then goes through additional 2.7µm and 0.7µm membranes (see diagram).

In order to extract the ATP contained within any organisms in the concentrate and filtrate solutions, Aqua Tools uses a technology it calls ATPprep beads, to 'beat' open any living cells present within the solution. Following this the solution is tested for its bioluminescent reaction.

Marc Raymond, founder and CEO of Aqua-tools, who personally developed the technique explains: "This means I can go onboard a ship, make a sample and 40 minutes later I have the information concerning whether my ballast water is compliant. This kind of indicative method is a good means of proving gross non-compliance, but we would expect that treated water should have zero ATP. If the result indicated living cells the sample would be taken for more analysis, but it would take 40 hours for a result."

The processing time of samples is likely to become an increasingly critical factor as port state control authorities begin in earnest the 'experience building' phase of the Ballast Convention timeline. In 2017, Singapore's Maritime Port Authority introduced ballast monitoring, with around 10 percent of the 350

vessels arriving daily being subject to inspections for compliance. Another authority is Saudi Aramco (see p.31), and Aqua-tools is among those attempting to persuade the Kingdom's port state control authority of the advantages of its particular analysis technology.

With this in mind, the company can point to a recent paper, 'A Shipboard Comparison of Analytic Methods for Ballast Water Compliance Monitoring', published in the *Journal of Sea Research*, which found during tests of various techniques that only the ATP method was able to detect all 'living' bacteria, irrespective of their species or if they were growing or injured cells.

Looking ahead, Raymond believes the effectiveness of ballast sampling will be dependent on establishing protocol for when and how samples should be taken and is hopeful that clearer recommendations will emerge following the next meeting of IMO's Pollution Prevention and Response (PPR) sub-committee in February: "We need to determine what volume of water we should be sampling, whether it's one cubic metre or three. We also need to work out how many tests we should be doing during the first phase of the de-ballasting, during the middle phase and at the end, because potentially the concentration of bacteria won't be the same. The more sampling you have the more accurate your results." **NA**

Survival of the fittest

Coldharbour Marine CEO believes at least 50% of the ballast water treatment system companies could be gone in five years as a result of the IMO's two-year extension of the BWM Convention

Speaking at a press event hosted by the Nottinghamshire-based ballast water management system (BWMS) and inert gas generator specialist late last year, Andrew Marshall, CEO of Coldharbour Marine, took the opportunity to comment on the ramifications of the IMO's decision to move the implementation of the Ballast Water Management Convention back by two years. Marshall said: "I think it's probably dropped a few thousand [vessels] out that would have had to have been retrofitted, but if you were relying on that bit of the market to make your money then you probably shouldn't have been in the market in the first place.

"The market cannot support 65 ballast water treatment companies, it can't support 45 companies. It can maybe support 15... The tragedy is, I think some good systems will go and some systems that really shouldn't be staying will remain."

However, he does see a silver lining to the decision for those companies that are able to weather the storm: "I actually believe that the market is slightly bigger than people think. What I actually think

Coldharbour's system is particularly suited to larger vessels requiring long ballast hauls



Coldharbour Marine's CEO, Andrew Marshall

will happen is that those companies that have gone bankrupt, if you look at the USCG ruling on what happens to a ballast water treatment system if the manufacturer has gone bankrupt, if the part supplier isn't there, you've got to replace the system. So there'll be retrofits of retrofits."

If Marshall's prediction is realised, the choice of BWTS systems will have depleted dramatically in the next five years compared with the range of systems currently on offer. Marshall's advice for shipowners? To do their homework and choose a system that's fit for purpose: "It's naïve of owners to think that just because a system has a certificate that it's going to work as they want it to."

Coldharbour Marine's own system, GLD (Gas Lift Diffusion) Ballast Water Treatment System, is, in Marshall's words, unsuitable for 85% of vessels worldwide. The company has instead opted to specifically target large tankers, bulkers and LNG/LPG carriers that have high ballast pumping rates, large ballast volumes and long ballast voyages, as Coldharbour's technology is best suited to these operating conditions. The company also recommends that its system only be installed on vessels with voyages of longer than five days, so that it has sufficient time

to kill the organisms. The minimum hold time is 60 hours, but the longer the ballast water is subjected to the uninhabitable conditions, the longer the system can deter the regrowth of organisms.

The GLD system has no mechanical equipment and instead works on the principal of fluid dynamics. At any point during the ballast voyage, inert gas can be injected into the gas lift diffuser to mix with the ballast water in the tank. This mixture is less dense, so rises to the top of the tank and new water is drawn in from the bottom, thereby stirring the contents of the tank. Air-breathing organisms are killed by the inert gas' deoxygenating effect on the water and other marine life, unaffected by the lack of oxygen, are killed by ultrasonic shockwaves caused by the gas. Increased levels of CO₂ also temporarily make the water acidic, further ensuring that the water is treated as thoroughly as possible.

What's more, because Coldharbour's offering means ballast water is treated in-tank and during the ballast voyage, there is no disruption to the vessel's schedule, and the treatment can even be scheduled to complete just before de-ballasting, to ensure that discharge standards are met. The GLD system is also self-calibrating, self-controlling and self-diagnosing, meaning crew do not have to be trained in order to operate it.

Marshall says Coldharbour Marine is on target to install 50 of its GLD systems per year within the next few years, and despite his concerns surrounding the delayed IMO Convention implementation, is optimistic about the company's future.

Despite some owners choosing to opt for whichever system will cost them the least money, Marshall is hopeful that change is on the horizon: "There will always be a market for cheap stuff because people will want to flip it [the vessel] on. It's going to take 10 or 15 years for wisdom to spread across the market." **NA**

Two-year tanker trial confirms Selektope antifouling power

The antifouling performance of the unique, bio-repellent antifouling ingredient Selektope has been verified during a 24-month trial on a 46,067dwt chemical and products carrier. In an exclusive report, *The Naval Architect* reveals the results

Average global water temperatures are increasing, a by-product of climate change's tangible impact on the oceanic environment. This warming is intensifying so-called 'biofouling hotspots' across the globe meaning that vessels trading or laying idle in such waters, particularly those in subtropical/tropical areas, require antifouling coatings that offer enhanced protection against biofouling.

For ship operators, the drive for vessel efficiency remains. A heavily fouled hull is extremely impactful on fuel consumption and maintenance costs. Adding to that, growing regulatory movement against the transportation of invasive aquatic species (IAS) by the international shipping fleet and intensified focus from the IMO on IAS transfer via biofouling, through the establishment of their GloFouling project, means that operators are demanding more from antifouling coatings than ever before.

The growing problem of biofouling build-up on vessels experiencing extended periods of static activity is also becoming an increasingly dominant issue on the agenda for many shipyards. Newly launched vessels remaining stationary for three or four months, or longer in the case of LNG carriers, during the fitting out process are becoming so fouled that they perform badly during sea trials.

Therefore, the pressure is on manufacturers to formulate antifouling coatings that can guarantee performance no matter how a vessel's activity or trading pattern changes, influenced by changing market conditions and regulatory pressures.

One antifouling technology that is stimulating advances in coatings



2010-built *Calypso* was selected to trial the Selektope-containing antifouling coating due to her regular operation in global biofouling hotspots

innovation for improved hard fouling prevention is the biocide Selektope, created and commercialised by Swedish bio-tech company I-Tech AB. Fifteen years of intensive R&D was undertaken by the company before the first antifouling coating products for ocean-going vessels were brought to market in 2015.

I-Tech's 'Eureka' moment at the start of the century yielded an organic, non-metal compound that works to prevent barnacle fouling by temporarily activating the swimming behaviour of the cyprid larvae coming into close proximity of the Selektope-containing coating, thus making it impossible for them to settle on the hull.

The first-of-its-kind antifouling technology caught the attention of coatings suppliers in the early stages of its research and development. To-date, several products have been launched

onto the market and the number of Selektope-containing coatings being sold by different manufacturers is increasing year-on-year.

This is due in part to the biocide offering efficacy at approximately 0.1% concentration within an antifouling coating's overall constituency. This low concentration means that the technology offers manufacturers the opportunity to use just a fraction of the active substance needed to achieve comparable performance with traditional biocides. Selektope is also flexible enough to boost copper-based formulations, but powerful enough to replace copper, giving manufacturers the added freedom to develop copper-free formulations.

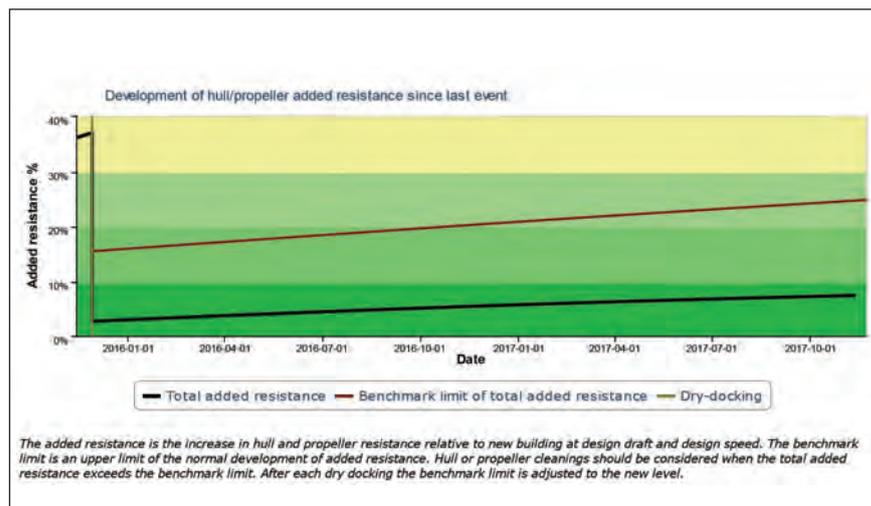
Interest from both the paint manufacturers and ship owners is complemented by continuously strong trial results for the technology. Recent

hull performance data for the 2010-built *Calypso* vessel endorses Selektope's antifouling performance. The vessel's hull was fully coated with a Selektope-containing product during its first five-year drydock.

The operating profile of *Calypso* during 2017 was similar to 2016, in which the vessel was in active operation across a wide range of trade routes. More than 50% of the vessel's operating time was in biofouling hotspots with > 25°C (up to 32°C) temperatures.

Twenty-four months out of drydock, *Calypso's* increased total resistance was calculated to be 7%, compared with a benchmark new vessel that would see an increase in resistance of 10-20%. This 7% increase in resistance corresponds to a mere 2% speed loss relative to sea trial performance. The increase in resistance from the propeller was 2%, with the remaining resistance being measured on the hull. Additionally, the independent analysis confirmed that the development rate of added resistance for *Calypso* is 0.1% (normally 0.5% to 1.5% is expected).

Daniel Kane, VP Sales at Propulsion Dynamics explains: "The expected development of hull and propeller resistance (benchmark limit of added resistance) is for similar chemical tankers of similar age and time-out-of-dock, assuming a spot blasted hull. *Calypso* had received a more extensive hull pre-treatment than the average chemical tanker on its five-year docking, yet the combination of blasting and



This CASPER graph charts *Calypso's* hull and propeller performance since the application of a Selektope-containing antifouling coating during drydocking in January 2016

coating have resulted in truly impressive results for hull performance."

Laurin Maritime's technical director Bertil Andersson comments: "The vessel has now operated for two years since last dry dock, and we can conclude that the fouling of the hull (read added hull resistance) remains at a very low level and the trend continues being flat."

"We continue to monitor the development via Propulsion Dynamics' CASPER reports and planned diving inspections arranged by the paint manufacturer. We hope that the positive experience remains over the upcoming three years to the next scheduled dry docking," says Andersson.

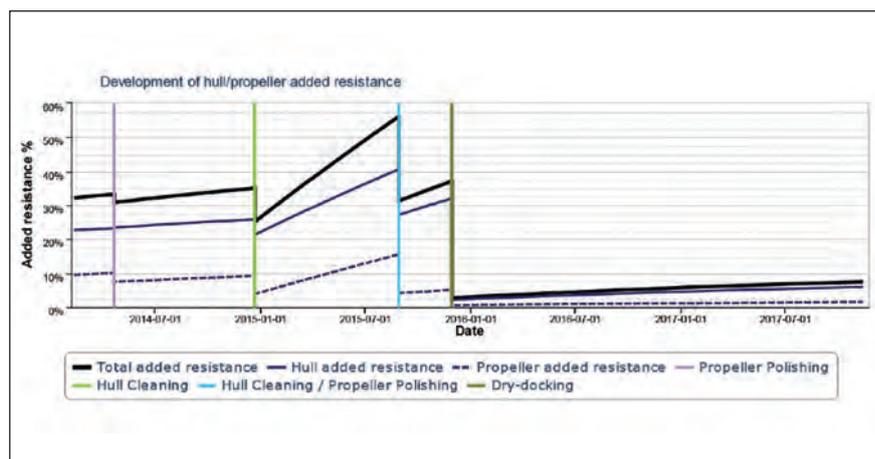
Andersson also adds that a recent underwater hull inspection confirmed that *Calypso's* hull is very clean without any

signs of attached barnacles and a very low level of slime. The inspection, conducted in November 2017 on the two-year anniversary of the vessel leaving its first five-year dry dock, revealed that divers found no sea life over the starboard and portside verticals, bilge areas and flat bottom, concluding that it is without antifouling loss after the last painting two years ago.

I-Tech CEO Philip Chaabane welcomes the impressive performance results for Selektope over an extended time period, saying: "This independent analysis of performance data and the underwater hull inspection provides convincing long-term performance results from a full-vessel application of a Selektope-containing coating with significant exposure to severe fouling conditions. This delivers the proof required that our unique antifouling ingredient can offer ship operators guaranteed hard fouling prevention performance for any vessel activity and trading patterns."

With global water temperatures having already warmed by 1-2°C, and with further temperature rises and intensification of biofouling hotspots anticipated, the requirement for more effective fouling control will certainly increase. What these results suggest is that Selektope is a serious contender to help ship operators futureproof their vessels through the maintenance of cleaner, more efficient hulls under all conditions. **NA**

Calypso has shown significantly less added resistance since its last dry docking



Experience capture in shipbuilding

Modern shipbuilding is a knowledge intensive industry, but how best for shipyards to capture information and expertise for future reference?

Yashwant R. Kamath and K. Sivaprasad believe Microsoft's SharePoint could offer the answer

Ships and boats have been designed and built well before the advent of modern naval architecture and shipbuilding processes. In some parts of the world, these traditions still exist, one example being the ocean-going Urus of the Malabar region of South India, where master craftsmen make seaworthy ocean-going wooden vessels without any documented naval architecture calculations or formal shipbuilding drawings. The craftsmen capture, preserve and reuse the experience of shipbuilding in traditional ways, which are usually neither documented nor disclosed to others [1].

But traditional information sharing methods lack procedures to formally record, transfer and reuse knowledge, and this is one of the major omissions of knowledge management systems in today's manufacturing industries.

Several information technology solutions have been developed to address the issue of knowledge management in manufacturing. The concept of Experience Capture is referred to by a number of different names and equivalent terms, including Knowledge Capture, Experience Reuse, Knowledge Reuse and Knowledge Transfer. As practised in the engineering industry, Experience Capture varies from individual record keeping [2] to the more sophisticated Knowledge Association Engine [3], which is supported by high end computing machines like the Apache Tomcat Server v6.0.

Llamas et al. [4] have stressed the need for having processes based on capitalisation and the use of experiences to improve agility in knowledge driven industries, which include manufacturing industries such as ship and boat building. But applying the Experience Capture mechanism to a shipyard requires that it be implemented at all levels of work, from skilled laborers employed on the shop floor to managers sitting in executive offices.

In order to use an Experience Capture tool effectively, the implementation proposal should focus on easy and user-friendly information technology solutions. In this context, Microsoft's SharePoint platform represents a possible solution. The main advantage of Microsoft SharePoint is that it is less complex in usage while offering immense scope for knowledge capture and database buildup for multi-level sharing.

While there has been step-by-step advancement in the development of ship building technology, some of the critical areas of shipbuilding still employ traditional methods. Unlike the automobile or habitat engineering industries the advent of automation and mechanisation in shipbuilding remains comparatively limited. A ship has a unique product status as an engineering entity, with its own

unique and eventful product development structure, during the stages of which a huge amount of data is created and exchanged.

But this data has great value in the event of sister ship construction or when series ships are built, particularly where series ships are attempted after a time break. The simple recording of the huge data generated during product development would prove of limited use due to the various changes in technology, methodology and human resources which occur with time. Moreover, a big cloud of data with no specific 'tag and address' system may act as a burden to the production engineers.

Need for experience capture

The lifecycle of an oceangoing vessel can be seen as a number of distinct phases (Figure 1).

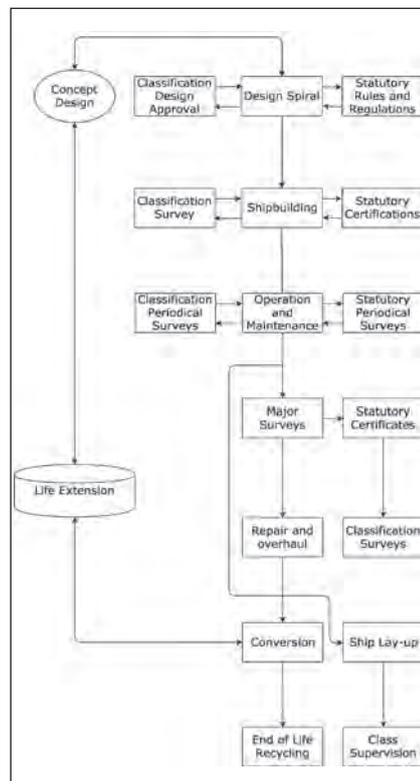
In all these phases, the product experiences numerous engineering issues and events. But with respect to the recording, compiling and analysing of engineering experience, engineers and skilled workers at various levels of production encounter problems. Management of an engineering experience database therefore becomes a real challenge, but systematic knowledge management offers a potential tool for efficient and profitable shipbuilding.

Compared to other engineering and manufacturing industries, shipyards tend to have significantly more production shops, employing a number of engineering trades and skills. Thus, in a shipyard, shipbuilding knowledge can be found widely scattered across different work platforms.

Shipbuilding departments in a shipyard generate a knowledge base, which is partly rulebook-based and partly subjective. Subjective experience capture is difficult but offers more scope in the development of a knowledge management system in shipbuilding.

SharePoint is a web-based tool from Microsoft. It is generally used as a simple collaboration platform, but some

Figure 1: Different Phases in Ship's Lifecycle



organisations configure it extensively to their needs. SharePoint is mated to a Microsoft SQL Server as a data server and Microsoft Internet Information Services (IIS) as a web server, both of which are backed by a Windows server. The installation of SharePoint may be on premises or online depending on the location of the server.

Within a shipbuilding context, SharePoint can be used as a platform for storing and sharing documents (e.g. drawings, key plans, reports etc), data storage (in this case 'experience'), enterprise content management, or as an internal website. In shared work situations, in which people or teams work homogeneously or cross-functionally, it can store and capture knowledge for their own and their successors' reuse. It can equally be applied for circumstances where people do similar work in different situations (e.g. Design subdepartments). There are also novices who may need occasional access to expert knowledge or guidance or those seeking to develop their knowledge in a secondary area.

Using SharePoint as an Experience Capture tool offers a number of advantages:

- *Enterprise search:* Since 2013, SharePoint has featured Enterprise search capabilities, indexing all the data (experience) in the entire corporate network, which may be highly heterogeneous and contrasting in nature. It ensures periodic reorganisation of the data, thereby creating summarised transcripts and purging all the redundant data.
- *Maintaining the context of data:* The database can be arranged and linked such that each record can be linked to all documents. It also helps in documenting related rulebook knowledge.
- *Mobile access:* The SharePoint website is actually a web app. Therefore, it ensures seamless access across all the devices irrespective of the operating system or screen size. Moreover, it can be easily accessed on-the-go with the SharePoint mobile app available on Android, iOS and Windows Phone devices.
- *Customisability and ease of setup:* The SharePoint website can be configured as easily as a social network page,

thereby reducing the company's investment in a core software team.

- *Usage rights:* The SharePoint Administrator can provide usage rights to each and every user in the organization to restrict his/her usage of data in any horizontal or vertical hierarchy, thereby ensuring the security of sensitive data.
- *Data entry and data extraction:* Data can be entered using customised forms, which makes it highly user-friendly. The forms ensure data is entered in all mandatory fields. Similarly, submitting data extraction requests using such forms facilitates easier data extraction.
- *Monitoring users:* The SharePoint Administrator can monitor and track each and every user, their activity and data.

SharePoint in shipbuilding

The entire shipbuilding, shiprepair and ship operation industry is valued on the basis of time. Deadlines and schedules fixed for a designer or engineer will often be so tight that, if a unique problem arises, the individuals won't be able to discuss this among the entire team. But upon solving the problem, the knowledge or 'experience' generated fails to be captured in the midst of tight schedules, resulting in extra work re-solving the same problem when it is faced again.

Very often multiple tasks are being carried out concurrently due to a product's various requirements. At present, knowledge is transferred among individuals and various projects by a variety of means, such as personal meetings, project evaluation meetings, technical inspections, informal inspections, owners meetings, job rotation and common project meetings. Some engineers keep a record of problems faced by themselves during their period of service in a handwritten book. Maintaining a spreadsheet is also a valid option for small scale or single projects.

Yet these do not provide a permanent solution to the problem of knowledge lapse or loss of experience. Firstly, the above-mentioned solutions are plagued by syntactical and semantic errors [5]. Secondly, the documents and consequently the knowledge or experience captured in them exist independently, not bound by any unified structure, again making it difficult to search for a solution.

The basic building blocks of the SharePoint Platform are SharePoint Site, Site Collections, and Sub Sites. In the platform we propose, a SharePoint Site will be declared for a shipyard, under which various Site Collections will be declared corresponding to each of the departments in that shipyard. Under each of the Site Collections there will be a number of Sub Sites (Figure 2).

The SharePoint site will have an administrator who is in charge of the entire platform and able to monitor all the information. The administrator can create the Site Collection for each department and assign administrator privileges limited to each Site Collection and individuals in charge of each department.

Each department will then have its own Sub Sites which might typically correspond to its various sub-departments, e.g. 'Electrical Design' and 'Hull Structure Design' Sub Sites under the Site Collection 'Design'. Sub Sites may be also configured to cater for problems in a regular departmental task, e.g. a 'Procurement' Sub Site in the 'Materials' Site Collection. User access can be set for each element of the SharePoint Platform, from public anonymous access to secure single-handed access. The Site Collection owner – the administrator – will have administration permissions limited to that particular SharePoint Site Collection.

Data entry and extraction are achieved through a form interface. Upon a successful match to a data request form, the result is displayed to the user in a data output form (Figure 3). If there is no exact match, a keyword search is performed on the database. Upon a successful match with one or more keywords, the data will be linked to the record with which the match was found. The user can also feed additional related documents to be stored along with the 'experience' he is feeding to the cloud, through the modified data entry form. If no match is found, and it is a unique and first-time experience for an individual in that shipyard, all the details along with related documents will be fed to the Experience Capture Platform. Over the course of time, it will be enhanced by continuous entry and extraction from different users in the shipyard.

Conclusion

Use of Microsoft SharePoint has been proposed after making suitable modification

Newbuildings nominated:

Lisboa
Elandra Eagle
Cardissa
Da Ji
Amjad
Celine (H/N 8205)
Ceilo Bianco (H/N S429)
Trammo Dietlin

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The Polar Regions see nearly 10% of the world shipping traffic. The receding ice in the North Sea Route and North West Passage offers new marine transportation options between the two major oceans and Europe, N. America and Asia. There are vast oil and gas resources around Siberia in the Barents and Kara Sea as well as in the Alaskan Chukchi Sea. Both poles also see a growing tourist inflow with the operation of many cruise ships close to the polar circles, as well as numerous ongoing scientific expeditions.

The introduction of the Polar Code at the beginning of 2017 for new vessels, and existing vessels in 2018, was a big step in creating safe conditions for the work and operation of vessels, as well as to protect the fragile polar environment. However the design requirements of the code have challenged operators and builders. New owners and operators are entering the market, in need for guidance on how to tackle these harsh conditions.

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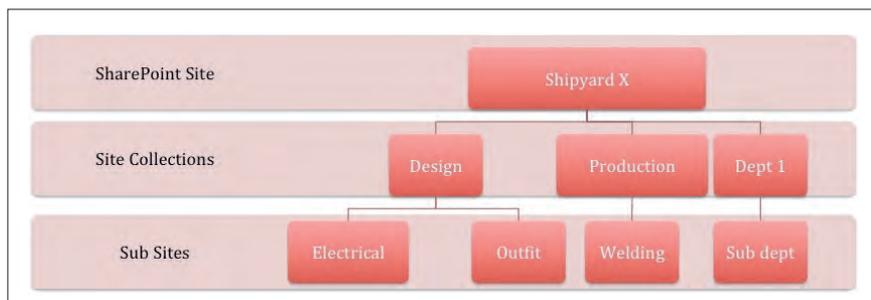


Figure 2: Part of SharePoint Platform Organisation

to its implementation in a shipbuilding context. Current limitations include the extra work an individual must do in entering the data, and the fact that the platform is effective only after it is fed with sufficient data. When the platform has years of existence, i.e. it has abundant data stored in it over the years, the platform can be made to evolve into a more intelligent platform by incorporating Design Failure Mode and Effect Analysis (DFMEA) or Process Failure Mode and Effect Analysis (PFMEA) to analyse the design or process and analyse the effects of potential failures.

This tool can be effectively coupled with Microsoft SharePoint for tapping the reuse of experience.

With large amount of data available, the Experience Capture Platform could become an Expert System by incorporating a Case Based Reasoning methodology. The system can be made more intelligent or human-like by exporting its data to an Experience Capture Platform using Neural Networks, or incorporating the same in the SharePoint Platform. *NA*

Figure 3: A sample Data Output form

About the authors

Sivaprasad K. currently holds the position of Associate Professor at Department of Ship Technology, Cochin University of Science and Technology, Kerala, India. His area of specialisation is Ship Production and Ship Repair with more than 20 years of teaching experience, and previously worked as a Senior Naval Architect at Mazagon Docks Ltd., India.

Yashwant R. Kamath is currently studying for a B.Tech in Naval Architecture and Shipbuilding at Department of Ship Technology, Cochin University of Science and Technology, Kerala, India.

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Contracting and delivering SD14s

The SD14 was the most successful British vessel of its type ever built. Ian Buxton has been researching how flexible building agreements made them profitable

Conceived as a replacement for the 10,000dwt, 10kn WW2 Liberty ships with steam reciprocating engines, a total of 211 Shelter Deck 14,000dwt, 14kn cargo vessels (SD14) were built between 1968 and 1988. Of these, 126 were constructed in Sunderland by designer Austin & Pickersgill and associated company Bartram, six to a similar design by Smith's Dock on Teesside, three at Robb-Caledon in Dundee, and a further 76 under licence by builders in Greece, Brazil and Argentina.

Full details of all the ships built and their careers, plus illustrations, are given in John Lingwood's splendid book, *SD14: The Full Story*¹. Further information on their contracting and delivery is contained in files on most of the Sunderland-built ships in the Marine Technology Special Collection at Newcastle University and in Tyne & Wear Archives, not previously published. They give an insight into a successful design which sold worldwide, was generally delivered on time and usually made a profit for the builder – not always true of British shipyards at that time. Many of the early orders were for Greek shipowners, encouraged by Basil Mavroleon of London & Overseas Freighters, the company that owned the A&P shipyard until it was nationalised under British Shipbuilders in 1977.

The contract price in sterling was derived from a basic price for a somewhat austere specification. However, it was always recognised that there would be owners willing to upgrade the specification, so a list of 'optional extras' with prices was provided. Accepting any of these at pre-contract stage meant they could be added as an allowance for extras to the basic price and thereby included in financial and credit negotiations, so that the owner more or less knew what their total outlay would be. Modifications agreed after contract (and there were often quite a few) had to be paid in cash. The final price would be adjusted up or down if the actual extras and credits came to a higher or lower figure. Typical extras included full air-conditioning in the accommodation,



Austin & Pickersgill's South Dock Yard No. 437 SANTA AMALIA on trial at ballast draft. She was delivered to Colocotronis on 9 March 1973 for £1.607M

tunnel side tanks (which levelled off the bottom of No.5 Hold into which the shaft tunnel protruded), CO₂ fire extinguishing system in the cargo holds, masts for the cargo winches (otherwise on the upper deck) and additional spare parts. The higher class owners who anticipated charters to liner companies would add further extras such as 10ton derricks in place of 5ton, a heavy lift derrick (typically 30-80tons), more powerful diesel generators (e.g. 3 x 350kW in place of 3 x 280kW), additional crew accommodation, a higher paint specification, St Lawrence Seaway fittings, better nav aids (though sometimes these were owner's supply if they had leasing arrangements), bridge automation and a sewage system. For the basic ships, such extras might be as little as 1-2% of the contract price, while in the higher class ships, around 14-16%; most, however, were in the 5-9% range. 1% commission was typically paid to any sale and purchase shipbroker involved.

Over the years the specification improved, with four series being designed. With the change in freeboard from the 1966 Load Line Convention, the draft and deadweight increased before the first ship was delivered, so the latter typically became about 14,900tons – about 240 higher when expressed in metric tonnes. The early

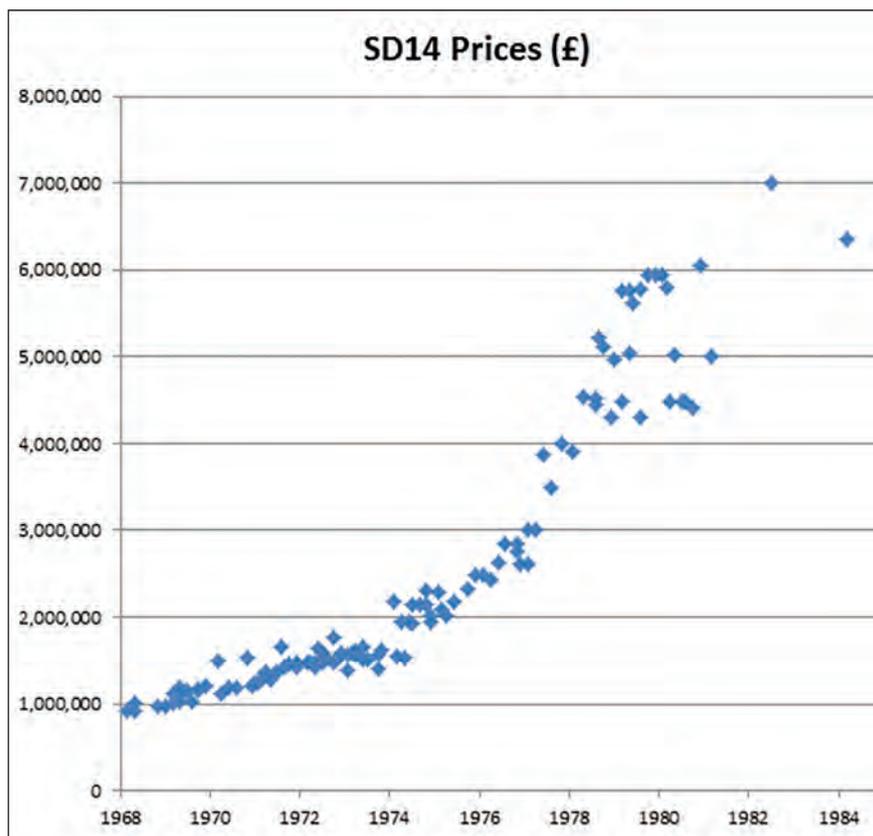
ships had 5-cylinder Sulzer 5RD68 engines of 5,500bhp, but 1971 deliveries received the 5RND68 engine of 7,500bhp, which gave 14.9knots when loaded. From about 1978 the 4RND68M engine of 7,600bhp gave a similar speed. Most of the engines were built by George Clark & NEM at Wallsend or Hawthorn Leslie at Newcastle, but installed by A&P. The main engine made up typically 12-18% of the price.

The contracts (building agreements) were fairly standard, with instalments payable typically being 5% on contract signing, 15% when 20% of the steel had been delivered, 15% when steel erection commenced, 15% when 1/3 steel erected, 15% when 2/3, 20% when launched and 15% when accepted. Up to about 1976, loans of 80% of contract price were generally available from a merchant bank in London, often Williams and Glyn (which became a subsidiary of the Royal Bank of Scotland from 1979). Later, loans of 70% over seven years were offered. For overseas buyers, such loans could be insured through the UK Export Credits Guarantee Department which charged a premium of typically 2.5%. The delivery date was specified, but liquidated damages for late delivery could be as low as £75 per day reckoned after the first 30 days, up to £500. If the ship was more than 12 months late, it could be rejected with the shipbuilder

returning monies paid back to the owner and the bank, but receiving title to the ship, which could then be resold. The agreement included a bonus (or penalty) for each ton deadweight more (or less) than contracted, typically at £80 per ton, but only payable after a margin of 100 tons. There was also a modest penalty (liquidated damages) if the speed on trial fell more than 0.25 knots below contract, at about £2500 per 0.25 knot, with the right to reject the ship if it fell below 1 knot – unheard of for SD14s. There was also a fuel oil consumption guarantee, but this was more an issue for the engine builder and designer. The guarantee against defective material or workmanship covered 12 months after delivery.

Most contracts were fixed price (before extras and credits) so A&P only took orders about two years in advance as production slots could then be guaranteed and there was less risk of inflation. But with rapid inflation in the UK in the early 1970s, some price variation clauses (escalation) were included covering about half the total cost – both wage levels and steel prices had doubled in the UK over four years to the early 1970s. Final prices to the shipowner as delivered (i.e. excluding any subsidy such as Intervention Fund payments paid to A&P) are available for most of the Sunderland built ships. As can be seen from the figure, the price increased from about £950k to about £6M over 15 years, mostly due to inflation but also to improved specification and new regulations. A few low prices were not typical, e.g. resales during freight market slumps, while higher ones often reflected more extras. Man-hours to build early SD14s were typically about 250,000, giving profit margins of around 10%. But the man-hours rose up to about 400,000 for later, admittedly more complex, ships, often resulting in a loss in those more competitive markets.

The actual delivery date would be proposed to the owner a few weeks beforehand, usually with ship handover at Sunderland. This would be a few days after the ship had been drydocked for about 4-6 days for final painting and underwater work, often on the Tyne. A large number of certificates were required from the shipbuilder and the classification society by the shipowner, bank, ECGD and their solicitors. The acceptance form (with place, date and time) would be signed by a senior member of the shipowner's staff, sometimes an engineer superintendent,



70s inflation led to a steep rise in SD14 prices

after the final instalment had been paid. The trials were run often only one or two days earlier, nearly always in a single day, with anchor and steering gear trials in the morning and speed and endurance trials in the afternoon (at typically three rpm on the Newbiggin measured mile north of the Tyne). Insurance was arranged for the trials and all personnel on board. A typical head count was about 112 – 6 A&P directors and managers, 6 design/drawing office staff, 7 foremen, 13 engine fitters, 13 riggers, 13 tradesmen (such as joiners, plumbers, electricians, shipwrights and painters), 6 engine builders staff, 19 subcontractors' representatives, 7 owners, 8 ship's crew and 14 caterers – extra lifesaving equipment being required compared with the usual two 31-man lifeboats. After handover, the ship would usually sail the next day – often with a charter already fixed.

Derek Kimber (a past President of RINA) and Mervyn Hargroves give details of the extended A&P shipbuilding facilities at Southwick – the former Bartram South Dock yard had closed in 1978. By the early 1980s, the simple tweendecker with limited

container capacity had given way to the full container ship, the bulk carrier and the multi-purpose ship with substantial crane and container capacity. The last SD14s were scrapped about 2015, often after half a dozen name/ownership changes. *NA*

About the author

Ian Buxton is a naval architect and RINA fellow with a wide interest in maritime affairs and history. He was latterly visiting professor at Newcastle University's School of Marine Sciences and Technology.

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- 2 Escalation clauses had been common in British shipyards in the late 1940s/early 1950s with long delivery times, although usually only applying to labour and materials, with a fixed figure for overheads and profit.
- 3 D Kimber & M Hargroves, *Creating a Production Facility for Standard Ships*. Trans. RINA 1977.

The Royal Institution of Naval Architects

International Conference:
Damaged Ship IV
16-17 May 2018, London, UK



Call for Papers

Recent incidents at sea have shown that investigations and understanding of the behaviour of damaged ships are as important as ever. Significant progress has been made over the last 10 years but there still remain numerous scientific and practical challenges.



After any major accident it is imperative to rapidly quantify the damage, assess damage stability and the residual strength of a vessel. Damage stability appraisal must also consider the likelihood of progressive flooding, the effect of the mass and motion of flood water within the vessel, capsizing probability and effect of waves on stability. There is a need to consider both the global strength capability of the ship structure and the local residual strength of damaged and buckled plating and the effect of flooding on internal structure.

Please submit your abstract before 15th January 2018

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conference@rina.org.uk Tel: +44(0)20 7235 4622 Visit the website

www.rina.org.uk/Damaged_Ship_IV

The Royal Institution of Naval Architects

International Conference:
**Propellers -
Research, Design, Construction & Application**
21-22 March 2018, London, UK



REGISTRATION OPEN

Influenced by IMO regulation on energy efficient design index (EEDI), the demand of energy saving devices (ESDs) is expected to keep growing. Its design requires a deep knowledge of the flow behaviour in the aft area of the vessel and highly advanced CFD simulations are required in order to properly characterise the hydrodynamic efficiency due to the propeller/hull interaction. This conference seeks to investigate some of these topics, including:



- Contra-rotating propellers
- Twisted rudders
- Pre- and post-swirl stators
- Vane wheels
- Rudder bulbs and rudder fins
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- Propeller cavitation

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LAMENTABLE INTELLIGENCE FROM THE ADMIRALITY

By Chris Thomas

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

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

SHIPS AND SHIPBUILDERS: PIONEERS OF SHIP DESIGN AND CONSTRUCTION

By Fred Walker FRINA

Ships and Shipbuilders describes the lives and work of more than 120 great engineers, scientists, shipwrights and naval architects who shaped ship design and shipbuilding world wide. Told chronologically, such well-known names as Anthony Deane, Peter the Great, James Watt, and Isambard Kingdom Brunel share space with lesser known characters like the luckless Frederic Sauvage, a pioneer of screw propulsion who, unable to interest the French navy in his tests in the early 1830s, was bankrupted and landed in debtor's prison. With the inclusion of such names as Ben Lexcen, the Australian yacht designer who developed the controversial winged keel for the

1983 America's Cup, the story is brought right up to date.

Price UK £12.50 EUR £16 OVS £18
AMAZON PRICE: £21.25

THE ROYAL INSTITUTION OF NAVAL ARCHITECTS 1860-2010

Published to commemorate the 150th anniversary of the founding of the Institution, The Royal Institution of Naval Architects 1860-2010 provides a history of the Institution as reflected in the development of the naval architecture profession and the maritime industry over that time. In the book, members give their personal views on the development of their sector of the maritime industry and how it will develop in the future.

Price UK £5.50 EUR £6 OVS £7
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2018

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Non-Members Part Ref: IJME18 Set Ref: ST118

Part A1	Part A2	Part A3	Part A4	Set
£25	£25	£25	£25	£83

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



International Journal of Small Craft Technology (IJSCT)

2018

Members Part Ref: IJSCT18 Set Ref: SS18

Part B1	Part B2	Set
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quarterly publication
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January 20-28, 2018

boot Düsseldorf

International exhibition,
Düsseldorf, Germany
www.boat-dusseldorf.com

January 23-24, 2018

Smart Ship Technology

International conference, London, UK
www.rina.org.uk/Smart_Ships2018

January 24-26, 2018

Vietship

International exhibition,
Hanoi, Vietnam
www.viet-exhibition.com.vn

February 21-22, 2018

Design and Operation of Ice Class Vessels

International conference, London, UK
www.rina.org.uk/Ice_Class2018

February 26-27, 2018

Basic Naval Architecture

Training course, Glasgow, UK
asranet.co.uk/Courses/BasicNavalArchitecture

March 12-14, 2018

CMA Shipping 2018

International conference & exhibition,
Stamford CT, USA
www.cmashipping2018.com

March 14-16, 2018

Asia Pacific Maritime (APM) 2018

International exhibition, Singapore
www.apmaritime.com

March 21-22, 2018

Shipping2030 Europe

International conference,
Copenhagen, Denmark
http.maritime.knect365.com/shipping2030-global/

March 29-30, 2018

Advanced Design of Ship Structures (includes Common Structural Rules)

Training course, Glasgow, UK
asranet.co.uk/Courses/AdvDesignofShipStructuresCSRS

April 11-13, 2018

Sea Japan 2018

International exhibition, Tokyo, Japan
www.seajapan.ne.jp/en/

April 12, 2018

RINA Annual Dinner

London, UK
www.rina.org.uk/Annual_Dinner_2018

April 17-20

Arctic Shipping Forum

International conference,
Helsinki, Finland
http.maritime.knect365.com/arctic-ship-ping-forum/

April 18-19, 2018

SURV 9 - Surveillance, Search and Rescue Craft

International conference, London, UK
www.rina.org.uk/Surv_9

April 18-20, 2018

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International conference,
Oslo, Norway / on board *Color Magic*
www.shippaxferryconference.com

April 23-24, 2018

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International conference,
Hamburg, Germany
www.greenmaritimeforum.com

April 24-25, 2018

TOC Asia

International conference, Singapore
www.tocevents-asia.com

April 24-26, 2018

Singapore Maritime Technology Conference

International conference, Singapore
www.smtcsingapore.com

May 2-4, 2018

Danish Maritime Fair

International exhibition,
Copenhagen, Denmark
www.danishmaritimefair.dk

May 9-11, 2018

Contract Management for Ship Construction, Repair and Design Course

Training course, London, UK
www.rina.org.uk/Contract_Management_Course_May_2018

May 16-17, 2018

Damaged Ship IV

International conference, London, UK
www.rina.org.uk/Damaged_Ship_IV

May 16-17, 2018

NaviGate

International exposition,
Turku, Finland
www.turunmessukeskus.fi/en/eventnavigate

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Posidonia 2018

International exhibition,
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www.posidonia-events.com

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Training course, London, UK
www.rina.org.uk/Basic_Drydock_Course_June_2018.html

June 14-15, 2018

Warship 2018: Future Surface Vessels

International conference, Bath, UK
www.rina.org.uk/events_programme

June 20-22, 2018

NAV 19th International Conference on Ships and Maritime Research

International Conference, Trieste, Italy
www.atenazionale.org/nav/nav2018/

September 4-7, 2018

SMM 2018

International exhibition,
Hamburg, Germany
www.smm-hamburg.com

September 26-27, 2018

Human Factors

International conference, London, UK
www.rina.org.uk/Human_Factors2018

October 12-13, 2018

Education & Professional Development of Engineers in the Maritime Industry

International conference,
London, UK
www.rina.org.uk/EPD_2018

October 24-25, 2018

Full Scale Performance

International conference,
London, UK
www.rina.org.uk/events_programme

December 5-6, 2018

Historic Ships

International conference, London, UK
www.rina.org.uk/events_programme

The Royal Institution of Naval Architects



**International Conference:
Smart Ship Technology**
23-24 January 2018, London, UK



Registration Open

Following on from our successful Smart Ship conference the Royal Institution of Naval Architects is organising a second international conference to further explore some of the key issues and themes raised by the first conference.

Developments in both information and communication technologies (ITC) have had a significant effect on many industries within the last decade. However, it is now just starting to impact the shipping industry. ITC will enable some of the most fundamental changes to the way ships are designed and operated. While there are still technical issues to overcome it's the non-technical hurdles such as economic and legal considerations that will define the rate of this progress.



The concept of Smart Ships covers a whole range of possibilities from predictive maintenance, performance optimisation, decision support tools, increased automation and robotics, unmanned remote or autonomous ship operation.

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www.rina.org.uk/smart_ships2018

The Royal Institution of Naval Architects



**International Conference:
SURV 9: Surveillance, Search & Rescue Craft**
18-19 April 2018, London, UK



Registration Open

With ever greater recreational and commercial use of the marine environment there is inevitably a higher rate of incidents where external assistance is required. This increased pressure on resources provides a new set of challenges that organisations need to adapt to, in order to continue to provide their high level of service.



With a focus on smaller and faster vessels, few sectors of the maritime industry have seen greater innovation in design. Both commercial and recreational small craft have benefited from the inspirational ideas of designers - ideas which although perhaps considered revolutionary at the time, have had a longstanding impact on the design of small craft today. This conference aims to review the new and innovative technologies available to the small craft designer and builder.

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