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14

MAN B&W boost for LPG

8

ABB launches 'intuitive' DP system


24

Skoon planning battery infrastructure


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## 22-45 Features












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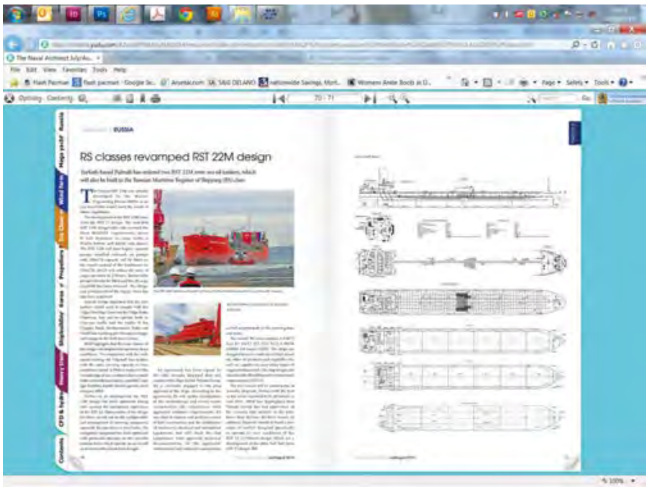


# The forecast remains grey

**Analysis suggests even with tougher $CO_2$ regulations a LSFO-fuelled Supramax bulker built today will still outperform nearly half of equivalent vessels in service in 2040**

Given that it was on home territory (at least for one half of the business) it was no surprise that DNV GL more or less held court at SMM in Hamburg, with a plethora of announcements, some of which you'll find covered in our News pages (p.8), overshadowing much of what the other classification societies had to say.

Curiously, however, they held back the official launch of a significant body of research until the following week in mid-September. The Energy Transition Outlook is a suite of reports exploring the likely changes in fuel demand and energy supply over the next 30 years, and builds upon a project initially launched last year. Of particular interest is the Maritime Forecast to 2050, which focuses on the concept of a 'carbon robust' ship design and evaluates how emerging fuel and technology options compare with traditional technologies with regard to $CO_2$ emissions and break-even costs.

"With this new framework, we hope to empower robust decision making on assets," said Knut Ørbeck-Nilssen, DNV GL's CEO of Maritime. Indeed, if nothing else the report represents arguably the first significant reflection on the issue of IMO's GHG targets and timeline since they were agreed in April.

By way of a case study the report looks at three different designs for a 55,000dwt bulk carrier (Supramax) that might conceivably enter service in 2020: a standard vessel running on MGO/LSFO (Design A), one running on LNG (Design B), and one running on MGO/LSFO but with additional investment in energy efficiency such as optimised hullform and auxiliary systems, as well as autopilot (Design C).

These hypothetical vessels were then run through two different scenarios to see how they might fare compared to the overall Supramax fleet over the next 20 years: a 'worst case' one in which little regulatory progress is made towards GHG reduction (the 'Dark Blue' scenario); and the obverse in which the Energy Efficiency Design Index (EEDI) is strengthened, a fuel levy of US$50 per tonne of $CO_2$ is introduced and there's a swifter uptake of alternative fuels ('Light Green').

The study suggests that higher emitting vessels will find themselves at a competitive disadvantage in the event of harder-hitting $CO_2$ regulations. Unsurprisingly, DNV GL is keen to emphasise the long-term advantages of LNG here, noting that by 2040 only 24% of the fleet will outperform Design B in terms of $CO_2$ emissions and just 16% bettering it in the daily break-even rate. After 20 years the higher investment has been absorbed (and, one assumes, bunkering infrastructure will have been established).

Still, from an environmental perspective, it has to be a concern that even Design A, with nothing in its favour aside from low-sulphur fuel, still beats 49% of vessels for $CO_2$ in the eco-conscious Light Green scenario. In other words, even in the best of possible worlds a fairly standard bulker ordered today in readiness for the 2020 sulphur cap might still have better $CO_2$ performance than half the vessels in service 20 years from now.

In spite of this, the study has been grounded on the assumption that IMO's GHG reduction targets will be achieved and shipping will meet its agreed carbon obligations. Energy use in the sector is anticipated to rise from 11exajoules (EJ) in 2016 to 13EJ by 2035, but then revert to the earlier figure by 2050 as efficiency measures become widespread. During the same period seaborne trade is predicted to rise 32% up to 2030 and then slow down to 5% growth from 2030- 2050.

But as has been covered within this magazine on a number of occasions, there's evidence to suggest the EEDI, to take one example, could have comfortably been more stringent than its current requirements. If growth in trade is really to be so exponential in the next 12 years isn't there an argument for saying that the industry could easily tolerate faster rollout of carbon and efficiency regulation? Isn't it disingenuous to continually cite the lack of technological maturity when there are solutions, such as hybridisation and slow steaming, that could be viably implemented within a much shorter timeframe?

Much in the same way as the old adage that nature abhors a vacuum, opportunistic rhetoric about the inevitability of growth insinuates itself into the impasse (or least prevarication) concerning climate change. But given global warming is either a moral panic or pending ecological crisis perhaps this is more of a societal issue than one specific to the maritime industry.

There's no implication in the above that DNV GL can or should do any more than highlight the current state of affairs and draw some broad conclusions about where this might lead us, so that industry stakeholders are better informed. At the same time perhaps what's needed more than anything is some de facto leadership and proactivity from shipping's big players that decarbonisation might begin in earnest. For now the progress towards sustainable shipping is not so much dark blue or light green, it's decidedly grey. *NA*

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To access DNV GL's Maritime Forecast to 2050 report visit:
https://eto.dnvgl.com/2018/maritime

LNG

# DNV GL highlights LNG projects at SMM

Classification society DNV GL used SMM as an opportunity to showcase its ongoing LNG projects, particularly with shipyards in China. The society stated that LNG is now a 'viable solution', citing technical maturity, emissions reduction and increased availability, following concerns from shipowners. In their latest Energy Transition Outlook, DNV GL have forecasted that LNG capacity will double by 2040, with seaborne gas trade between North America and China set to treble by 2050.

During the fair on the 5 September, DNV GL signed a joint development project with Dalian Shipbuilding Industry Company (DSIC) regarding the development of a 23,000 TEU ultra large container vessel that will be fuelled by LNG. DNV GL said it will work DSIC on delivering a construction-ready design that meets incoming regulations, class standards and predicted market trends.

The following day, DNV GL CEO Knut Ørbeck-Nilssen presented Jiangnan Shipyard Group Chairman Lin Ou with an Approval in Principle for LNG JUMBO, a new LNG carrier design. The 175,000m$^3$ capacity vessel was designed by MARIC, and will feature a GTT MK III Flex Cargo Containment System. Propulsion will likely take the form of a WinGD X-DF two-stroke dual-fuel engine, allowing the vessel to meet IMO Tier III NOx requirements in gas mode.

Of the AiP, Ørbeck-Nilssen said: "As the gas segment continues to gain importance in shipping, new designs that offer greater efficiency and compliance alongside safety are important in advancing the segment, and we are very proud to support Jiangnan Shipyard in realising this new concept."

Dynamic Positioning

# New DP system from ABB

Vessel operations are defined using Marine Pilot Control's touchscreen

ABB has launched ABB Ability Marine Pilot Control, a touchscreen-based dynamic positioning system billed as "much more than a traditional DP" by senior VP of digital solutions Mikko Lepistö.

The new system is claimed to reduce the workload on automating navigational tasks by employing an algorithm able to calculate the optimal way of executing commands. The 'intuitive' interface is touchscreen based, although operators are able to switch to joystick control if this is recommended by the algorithm. Users are also able to define an area around the vessel which it is not permitted to leave, whilst keeping its heading, promoting safety.

A key feature of Ability Marine Pilot Control, says Lepistö, is that "the product can control the ship across the entire speed range." In conventional DP docking operations, Lepistö explains that ships tend to slow down before activating the DP, coming "to almost a complete stop. If you look at this operation, there's quite a lot of inefficiency." ABB's offering aims to bypass this transition, conducting navigational operations such as docking in the most efficient manner. As crew are able to focus on the vessel's surroundings, operations can be conducted faster without compromising safety.

The design of the DP looks towards autonomous shipping, says Lepistö: "To enable autonomous shipping, we need a DP system that replaces traditional solutions designed for disconnected operations. Embracing new technologies for the human-machine interface and offering tangible safety and efficiency benefits, ABB Ability Marine Pilot Control does exactly that."

The system is designed to work in tandem with the 2017-launched ABB Ability Marine Pilot Vision, a situational awareness product that provides real-time visualisation of the vessel's surroundings. It can also be connected to ABB's Collaborative Operations Center for performance monitoring and remote support. Approval in Principle was presented to the system at SMM by Lloyd's Register.

LNG

# Trio collaborate on LNG integration

Three industry leaders have announced their intention to work together to streamline the integration of LNGequipment on board vessels.

Two-stroke engine manufacturer WinGD, which has recently developed the X-DF dual-fuel engine, supplier of the LNGPac fuel handling system Wärtsilä, and LNG tank manufacturer GTT believe the collaborating will lead to an optimisation of the integration process between their respective equipment and help shipowners looking to use LNG on board their vessels.

The companies have a track record of working together on over 50 LNG projects. Their most notable

project thus far has been for CMA CGM, which has nine 22,000 TEU LNG-fuelled containerships on order. The size and number of the vessels ordered led many in the industry to re-evaluate LNG as a potentially mainstream fuel, despite it only powering 0.2% of the world fleet at present.

Speaking at a press event at SMM, WinGD's VP of sales and marketing, Rolf Steifel, said: "LNG is considered to become one of the major solutions to make the shipping industry more clean and more sustainable going forward into the future. In order to achieve that we need to collaborate."

Through the collaboration, clients of the respective companies are set to benefit from greater troubleshooting and assistance as the propulsion system can be delivered and maintained in a more holistic manner. It further represents Wärtsilä's Smart Marine Ecosystem ethos, which prioritises smart, digitised solutions in which integration promotes efficiency.

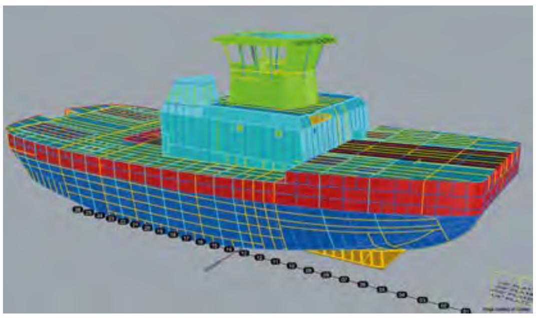
Concept design

## Crowley and ABS explore 3D models for class design review

American class society ABS and Crowley Maritime-owned naval architecture firm Jensen Maritime have finished a pilot project which explored the use of 3D CAD models in classification, as an alternative to traditional 2D drawings.

Increasing numbers of naval architects are creating concept designs in a 3D CAD environment, but are required by class societies so submit 2D drawings for design review because 3D models are not deemed to offer the requisite level of detail. However, improved modelling technologies, as well as advances in data management, have meant that 3D models are increasingly on a par and even superior to their 2D predecessors. By removing the need to create 2D drawings, time savings of 15-25% across the concept design process are expected.

Advances in 3D modelling open up possibilities for classification



ABS' vice president for technology, Gareth Burton, says: "Until now, only two-dimensional drawings have offered the fidelity of detail required to support ABS classification. But advances in technology and 3D modelling techniques now enable one end-to-end project model, backed by an extremely detailed data set, for plan approval."

From concept design to delivery and even operation, 3D CAD models are becoming increasingly important to naval architects, with digital twins prompting optimisation, improving safety and creating value throughout the entire ship life cycle.

LPG

## Lloyd's Register grants approval for HHI LPG-fuelled gas carrier

Classification society Lloyd's Register has granted an Approval in Principle to Hyundai Heavy Industries for a very large gas carrier (VLGC) design that will use LPG as fuel. The approval, announced at the Gastech conference held in Barcelona, follows a joint development project between Lloyd's Register, engine designer MAN Energy Solutions, and Hyundai Global Service, which has expertise in the conversion of LPGC vessels to LPG-fuelled propulsion systems.

LPG carried as cargo on VLGCs is an attractive fuel option for operators for reasons of both convenience and emissions reduction, as conventionally MDO or HFO would be used. However, there are numerous safety issues that must be taken into account for LPG burning and storage systems, including potential leaks and gas collecting in confined spaces. This is exacerbated by LPG being heavier than air. Therefore, prior to granting AiP, Lloyd's Register undertook a HAZID workshop for the fuel supply system, following the class society's ShipRight procedure for Risk Based Designs.

Man Energy Solutions' knowledge was sought throughout the process owing to the company's experience of developing the two-stroke, dual-fuel MAN B&W ME-LGIP engine, which operates using LPG as a low-flashpoint fuel.

Regarding the AiP, Hyundai Global Service CEO Kisun Chung remarked: "We have focused on developing the safe design for LPG-fuelled propulsion system. We are pleased to introduce the reliable design of VLGC with LPG burning system in the market for new building and also conversion vessels so that VLGC players can have environmentally friendly vessels and maximize their benefits using their cargo carried onboard the vessels." *NA*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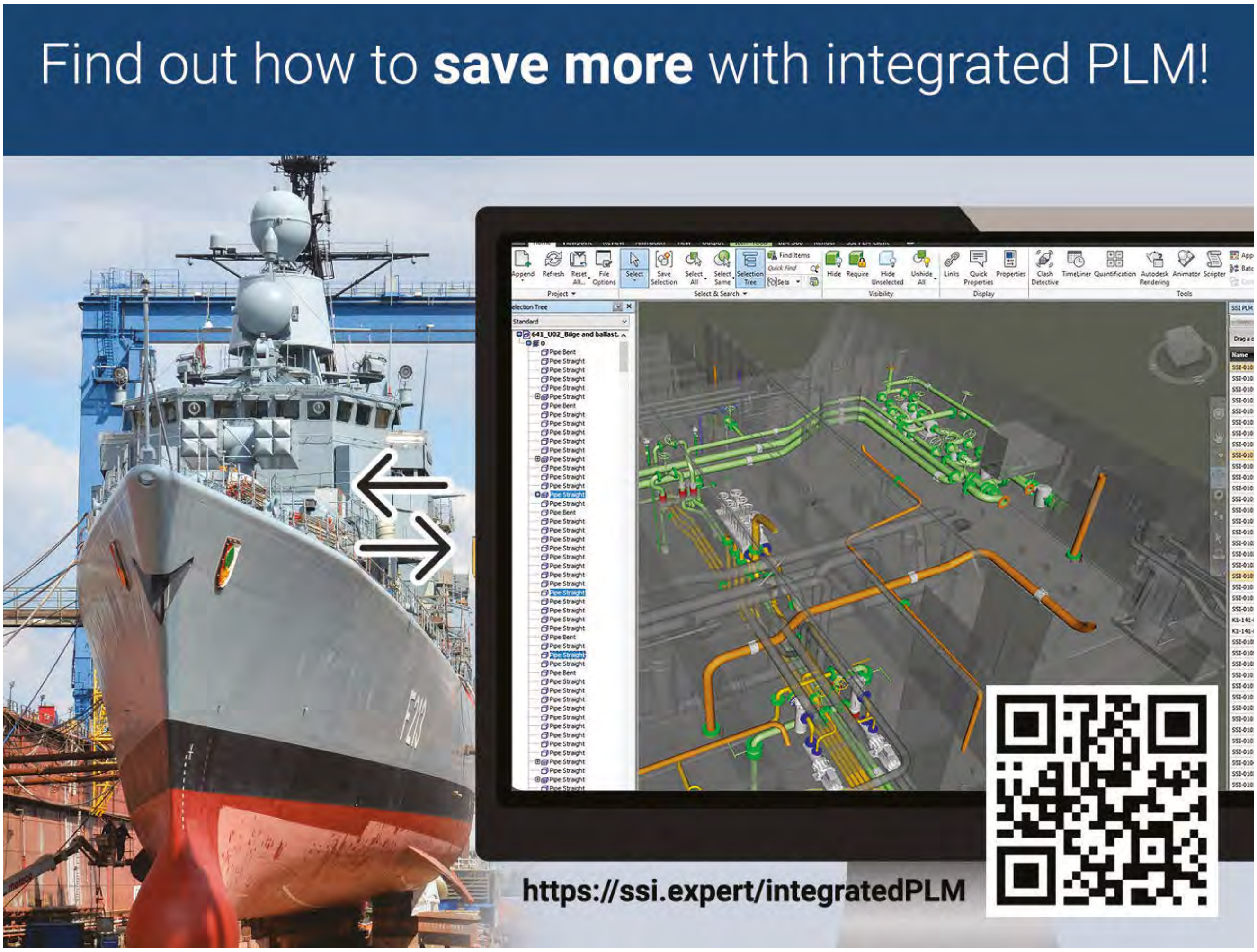
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# Lots of sales but a lack of steel

## Digitalisation, ballast treatment and scrubbers overshadowed power and propulsion solutions at SMM in September, but there was no shortage of announcements, writes Malcolm Latarche

As Europe and perhaps the world's largest marine equipment exhibition, SMM in Hamburg is the place to catch up on the latest technology advances. This year, the organisers had chosen a number of themes including Digitalisation and Green Propulsion under the title of 'Trends in SMMart Shipping' and in this regard the exhibition did not disappoint.

There was however something about this SMM that was a departure from the norm and that was the lack of heavy metal in most of the 13 halls. The lack of physical exhibits replaced by touch screens, tablets and VR was remarked upon by a number of visitors and exhibitors alike. Most notable was the lack of larger engines although in keeping with the digitalisation theme it was possible on the MAN Energy Solutions' stand to walk inside a virtual engine using a VR headset.

If there was a dearth of physical exhibits there was no shortage of announcements of new products and developments. Rolls-Royce Power Systems announced a new Bergen B36:45 LNG-fuelled lean-burn Otto cycle engine based on the oil powered B33:45 with identical power outputs at 600kW per cylinder at 750 rpm. The engine will be available in six, eight and nine-cylinder in-line configurations and there is a V-12 version in development which will be followed by a 20-cylinder V-engine for very high-power applications.

As well as the new engine, the company announced a new range of ELegance pods based on Permanent Magnet technology. The pods feature a 'twin tail' concept to further improve efficiency while claiming significantly reducing cavitation-induced noise and vibration. A new integrated hull fitting interface also allows a compact head-box to be used, which minimises drag and further improves hull efficiency. Rolls-Royce is now building a 4.6MW ELegance pod at its Rauma facility in Finland and is in discussions with shipowners to install the pod in a pilot project.

Every SMM brings announcements of new ship design projects and this year among those was an Approval in Principal by LR for Jiangnan Shipyard's jointly developed LNG dual-fuelled Newcastlemax 210K bulk carrier design. The design features dual-fuel LNG propulsion, with Piggybacked Type C tanks. The LNG-PTC will feature a dual-fuel main engine (MAN B&W ME-GI or WinGD X-DF), dual-fuel auxiliary engines, fuel gas system with pressure to suit engine type, cylindrical IMO Type C LNG tanks and a related safety system.

The same yard also received AiP from DNV GL for another vessel design. The LNG JUMBO is a new Flex LNG carrier design developed by Jiangnan Shipyard in cooperation with ship designer MARIC, GTT, DNV GL and major equipment manufacturers.

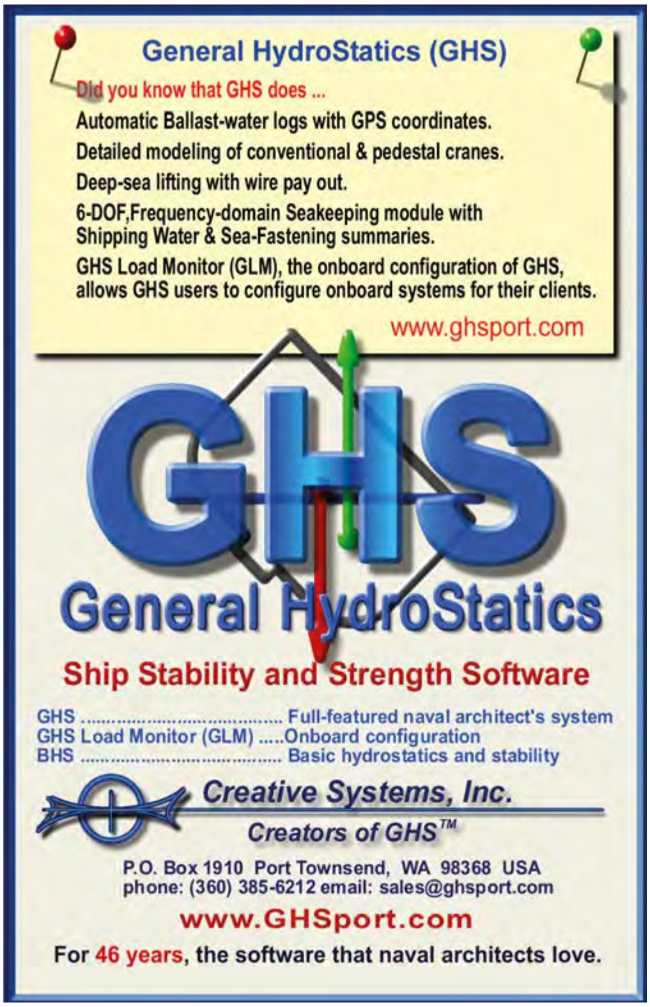
The ship uses the GTT Mark III Flex cargo containment system, and is equipped with four standard cargo holds for a total 175,000m$^3$ cargo capacity. The ship's shore connection is flexible and compatible with most shore facilities, and it can pass through the Panama Canal. The proposed WINGD X-DF low-pressure, low-speed two-stroke dual-fuel main engine propulsion system offers higher propulsion efficiency and lower fuel consumption in combination with an optimised twin skeg design and additional energy saving devices.

Two years ago at SMM there was a sense of elation among ballast treatment system makers when news broke during the show that Finland's signature on the 2004 Convention meant it would be finally coming into effect. Since then the IMO has effectively extended the installation programme and 10 systems have achieved US Coast Guard type-approval. The latest system to achieve that was Wärtsilä's Aquarius EC system which was granted its certification just days before SMM opened.

Ballast treatment was very much in evidence at the show with RWO announcing its re-entry to the market after a three year hiatus and also applying for US type-approval and new systems being announced by some other makers. Alfa Laval was particularly pleased with its securing of an order for 47 systems from tanker operator TORM.

There was even a new entrant to the arena in the shape of Singapore-based BOS which has devised a system around monitoring uptake of water and only ballasting with compliant water that requires no treatment.

As expected the impact of 2020 was a major talking point particularly the surge in the popularity of scrubbers as a means of compliance. As well as being a discussion subject at many of the conferences and seminars around SMM it was obvious from the number of makers exhibiting that the community of scrubber makers is ballooning at a rate that rivals the growth in ballast treatment system suppliers from 2008 until now. Such is the growing attraction of scrubbers it seems that even long-term sceptics such as Maersk and Hapag Lloyd are now considering installing them on some ships in their fleets. *NA*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Engines

## MAN officially launches LPG-capable two-stroke engine

MAN Energy Solutions officially unveiled its latest two-stroke engine type, the MAN B&W ME-LGIP (Liquid Gas Injection Propane), at a ceremony in Copenhagen on 3 September.

Based on its earlier ME-GI (gas injection) and ME-LGI (liquid gas injection) dual-fuel engines, MAN says it has launched the engine to further diversify its portfolio of non-HFO options that its two-stroke engines can exploit in response to customer demand.

MAN adds that as LPG will require less investment in bunkering infrastructure by comparison with gaseous fuels it represents a viable option for meeting 2020 sulphur requirements and, ultimately, IMO's 2050 targets for carbon reduction. It also constitutes part of MAN's 'Maritime Energy Transition', a wide-reaching initiative aimed at supporting a climate-neutral maritime industry.

Thomas Knudsen, head of MAN Energy Solutions Two-stroke division, said the ME-LGIP will consolidate the success of its predecessors, which have already won over 250 orders since entering production in 2015.

The ME-LGIP's characteristics include a low-pressure supply system, a fuel-injection system based on technology recently developed for its MDO/HFO engines, an injection pressure of 500-600 bar and the ability to handle low-flashpoint fuel types, be it methanol, ethanol, LPG or dimethyl ether (DME). Fuel flexibility has been designed into the engine so that it can tolerate LPG with significant ethane content.

It is also capable of burning volatile organic compounds (VOCs), which are widely anticipated to be subject to IMO clampdowns in the future, with this seen as making it an ideal choice for shuttle tankers and very large crude carriers.

March 2018 saw the first orders for the new engine when Hanjin Heavy Industries announced its Philippines subsidiary was to construct two 80,000m$^3$ very large gas carriers for Belgian gas giant Exmar, each to be powered by a 6G60ME-LGIP Mk9.5 engine.

**man-es.com**

The MAN B&W ME-LGIP engine is designed to handle low-flashpoint fuels

LPG

## Wärtsilä to provide LPG handling equipment for new Exmar carriers

Finnish technology group Wärtsilä has announced that it is to supply an LPG cargo handling and fuel gas system for two 80,000m$^3$ very large gas carriers ordered by Belgian fleet owner Exmar at HHIC-Philippines. The new vessels are the first capable of running on LPG, prioritising a sustainable operational profile.

Wärtsilä's 'LPG as fuel' technology is to be fully integrated with the cargo handling equipment, and will be controlled by a proprietary Nacos Platinum automation system. This platform, designed for optimal safety and operability, visualises data from the bridge, cargo control centre and engine room to deliver high energy efficiency.

Exmar's managing director of shipping, Pierre Dincq, said: "These are 'game-changing' gas carriers and our aim has been to achieve the best possible operational and economic performance, while at the same time, ensuring the lowest possible environmental footprint." The use of LPG is stated to complement Exmar's track record of LNG use and transport.

Wärtsilä and Exmar have collaborated previously on LPG projects, with Wärtsilä Hamworthy (the latter company now fully integrated in the Finnish technology group) supplying cargo-handling equipment to four 38,000m$^3$ Exmar carriers delivered by Hyundai Mipo Dockyard in 2014.

All equipment is to be supplied by mid-2019, with the carriers scheduled for delivery in late 2020.

**wartsila.com, exmar.be**

LNG

## Becker powers up portable cold ironing solution

German manufacturer Becker Marine Systems says that it is "very satisfied" with the results of a pilot project using the Becker LNG PowerPac, a portable power plant.

Developed in conjunction with Becker subsidiary HPE Hybrid Port Energy, the Becker LNG PowerPac is a compact system the size of two 40-foot containers which can be combined with a 1.5MW gas-powered generator


The PowerPac offers eco-friendly power for box ships

(upscalable to 3MW) and LNG tank to provide power while a ship is in port.

Once moored, the PowerPac is transferred on the aft of the vessel using the port's loading equipment. This enables large container ships to turn off their auxiliary engines and thereby drastically reduce NOx, SOx and fine dust emissions while berthed. Germany's Federal Ministry of Transport and Digital Infrastructure previously awarded Becker a seven-figure sum to assist with the technology's development as part of its mobility and fuel strategy.

Becker worked with freight operator Hapag-Lloyd in conducting multiple tests at the Hamburger Hafen und Logistik (HHLA) pier, involving Hapag-Lloyd's 20,000 TEU vessels. The PowerPac has been partly classified and risk assessed by classification societies DNV GL and Bureau Veritas. Becker is currently in dialogue with a number of European and Chinese ports about introducing the system.

**becker-marine-systems.com**

Shaft bearings

## Thordon Bearings to offer lifetime bearings guarantee

Canadian manufacturer of seawater-lubricated propeller shaft bearing systems, Thordon Bearings, announced a new lifetime guarantee for its COMPAC system at SMM 2018.

The extended wear life guarantee will supersede the 15-year offering currently in place, pledging that COMPAC polymer bearings won't need replacing 'throughout a vessel's operational life.' Specifically, the new guarantee states that COMPAC bearings are guaranteed to meet the appropriate Class Society's shaft bearing wear specification for the lifetime of the vessel. In the event that the bearings do not meet this specification, Thordon Bearings will supply new bearings for free.

The extension applies solely to operators of tonnage with shafts above 300mm in diameter. Vessels must also be fitted with a complete COMPAC system including Thordon Bearings' Water Quality package, ThorShield anti corrosion shaft coating, and SeaThigor forward seal.

Thordon Bearings decided to extend their original guarantee following analysis of 25 years of performance data for the more than 550 COMPAC shaft bearings in service on commercial vessels. The analysis reflects the average merchant ship lifespan of 25 years.

Speaking on the new guarantee, CEO and President Terry MCGowan said: "After evaluating the performance and operational data of the ocean-going merchant vessels that operate COMPAC seawater lubricated bearings we found that if the environment was controlled – ensuring an adequate supply of clean water consistently delivered to the shaft bearings – the COMPAC bearing wear was minimal."

**thordonbearings.com**

Sensors

## Intelligent Awareness system trialled on MOL ferry

Rolls Royce's Intelligent Awareness (IA) system has been verified in sea trials on Mitsui O.S.K Lines passenger ferry *Sunflower Gold*. The testing follows a 2017 joint development agreement, leading to the installation of the sensors, thermal imaging cameras and LIDAR equipment that comprise the system in April. Data from the trials and other projects including testing on board Finferries' *Stella* is now planned to be fed into a machine learning algorithm to improve the technology and pave the way for a permanent installation.

The IA system is designed to give navigators 'day-like' situational awareness in the hours of darkness, improving decision making and safety. It is able to detect navigational obstacles in real time through the combination of different sensor equipment, and visualises these hazards in a display which supports Virtual Reality, Augmented Reality and Precision modes (see May's *The Naval Architect*).

The choice of the 165m *Sunflower Gold* stems from the vessel's regular night-time sailing between Kobe and Oita, requiring transit via the challenging Akashi Kaikyo, Bisan Seto and Kurushima Straits. These routes are subject to congestion by fishing vessels and their nets, which represent a significant danger due to the high relative speed of the ferry.

Of the trials, MOL director Kenta Arai said: "We specified the configuration of Intelligent Awareness for our ferry with Rolls-Royce's advanced sensing and data fusion technology. The trial result was successful and we had good feedback from our crew. We are expecting to get a more effective and helpful system for our passenger ferry from the findings and the result of this project."

**rolls-royce.com/products-and-services/marine.aspx**

# Specifying shipbuilding contract deliverables

Kenneth W. Fisher highlights the tangibles, procedures, documentation and rights buyers should be aware of when detailing the contractual specifications with a shipbuilder

Numerous contract disputes arise when it comes time for the purchaser (usually a ship owner) to collect the contract deliverables from the seller (usually a shipyard). Suddenly, at a crucial time, the two parties realise that they have significantly different understandings of the content, form, format and timing of the deliverables.

The ensuing disputes are essentially differing interpretations of the ambiguously defined contract deliverables. Those problems typically arise due to either assumptions not being valid or lack of sufficient resources being applied to the contractual specification of the deliverables. Often the ship owner's specification writers believe they don't have to prepare lengthy specifications because "they know what we mean".

Actually no, they (the contractor or shipyard) do not know what you (the ship owner) mean. A word of advice to shipowners: spell it out in the contract specifications, with ample detail. When preparing the specifications for any design work, ship construction, ship repair or major items of equipment, the purchaser's team has to clearly define each and every one of the contract deliverables in terms of content, form, format, timing and (if applicable) place of delivery.


Trouble may await shipowners if they don't protect themselves with detailed specifications

## Tangibles

When a vessel is to be constructed, the delivery of the vessel itself constitutes the hand-over of the largest item of tangible property. If the owner is expecting the shipyard to turn over any other tangibles, the contract has to provide their identification and any relevant information about the delivery process.

For new construction, this is rarely a problem. But when a vessel is being converted to provide a different functional capability than it previously could accomplish, there are usually many items of materials and equipment that are being removed from the vessel that will not be re-used on the converted vessel.

The contract has to define the ownership of those items. The contractor may have included in pricing a credit for the sale of the scrap materials, unless the contract clearly states otherwise. If items of equipment are coming off the ship, are they to be preserved and removed carefully with a spanner, or can the contractor remove them with a cutting torch? If the removed items are to be sent to the owner's warehouse for use on a different project at some later time, which party is responsible for packaging and transportation? If control cabinets are being removed, temporarily or permanently, are all the cable connections to be labelled, or can the contractor ignore that step?

"Both parties need to actively monitor the issuance and receipt of deliverables"

The central theme here is that the owner's specification has to address every aspect of materials and equipment that is being moved off or onto the ship in order to ensure that the contractor has allowed for fulfillment of those responsibilities in its pricing and scheduling.

## Procedures

When a ship is being constructed, repaired or converted, numerous procedures are needed to demonstrate the proper installation of all operational equipment, including control, alarm and monitoring. Those demonstrative tests and procedures can be quite extensive, especially when data is being communicated between items of equipment from different manufacturers.

In order to allow the tests and trials to be adequately scheduled, the shipbuilder needs to know in advance, through the specifications, the number, extent and duration of such tests and trials. For any particular item of equipment, will a two-hour test in five conditions be sufficient, or does it have to be an eight-hour heat run incorporating 12 test conditions? Can electrical system tests be made using the ship's equipment as a test load, or does an external load bank have to be used?

This is particularly challenging if the shipbuilder is merely an observer to tests and commissioning being conducted by tech reps for owner-furnished equipment. In such instances, the shipbuilder needs to know in advance what support services and resources have to be provided, what conditions the tech rep needs to perform his tests, how those tests will impact the shipbuilder's schedule, etc.

A good example of a failure of the owner to identify the needed test procedures pertained to the agenda for dock trials and sea trials of a new special service vessel. The shipbuilding contract incorporated a detailed description of those trials. As construction was nearing completion, the owner's team realised that it had inadvertently inserted into the contract the trials agendas it uses for ship repairs, not for new ship construction. Upon discovering the error, the owner's team advised the shipbuilder that a far more extensive set of tests and trials was needed, as it was a new ship, not a repaired ship.

The shipbuilder presented a proposed change order incorporating cost and schedule impacts. The owner rejected it, expressing that it was unreasonable for the builder to expect that the owner would accept delivery with a limited scope of tests and trials. The builder responded by reminding the owner that adherence to the written contract is paramount, and that verbally altering the workscope (necessitating greater resource expenditures and having schedule impacts) without appropriate compensation (money and time) is not consistent with fixed price contracts.

The owner directed the builder to comply. A mediated post-delivery settlement resolved the issue, mostly in favor of the builder. It is noted that the costs of lawyers, experts, consultants and the mediator could have been avoided if the owner's team appreciated that the contract's fixed price and fixed schedule were based on the written contractual requirements, not on the owner's verbally expanded 'correction' of those requirements.

## Documentation

The number of documents that have to be delivered by shipbuilders to owners is often staggering. Many of the documents are 'process' documents, such as the megger reading for electrical cables, the temperature reading for coating applications, the comments on drawings. Those process documents have short lives, but many other documents have to move between the parties.

Owners may require a review of draft purchase orders and purchase technical specifications for major items of equipment before the shipyard issues the purchase order to the vendor. Open/inspect reports (condition or survey reports) during ship repair are plentiful. As-built and as-fitted drawings are long-life deliverables, as are

A new ship can generate a staggering amount of paperwork

the operating manuals for equipment and systems. Copies of the shipyard's communications with the classification society overseeing construction are sometimes contract deliverables. Draft test and trial agendas, subject to review and acceptance by the owner's team, are also often specified deliverables.

The list of documentation deliverables is not endless, but it is long. Both parties need a comprehensive list of all the contractually defined paperwork requirements. Both parties need to actively monitor the issuance and receipt of those deliverables to ensure that they are all achieved in a timely manner.

In addition to the documentation deliverables that are identifiable at the time of contract execution, the need for many others will arise in association with change orders. If the change order alters an element of vessel configuration, the corresponding ship documentation has to be altered as well.

An example of the consequences of a failure to follow-up on documentation for a change order involves a research vessel. The vessel was having a new model of a recessed array fitted to the bottom of the ship. Prior to arrival of the new array, while dry docked, the old array was removed after the pressure-compensating fluid was drained and the transparent faceplate was removed. The old array was slipped out between bilge and keel blocks, and the new array was brought in the same way. At that point, it became clear that the new array required a longer recess in the hull. The enlargement of the recess in way of fuel tanks and bilge blocks, constituting a surprise change order, was achieved, albeit painfully.

Four years later the vessel was entering dry dock for special survey. As the blocks contacted the hull, an oil sheen appeared. The cause was a broken faceplate, where bilge blocks that should have been permanently removed from the docking plan – but were not – landed on the faceplate. In other words, the failure four years earlier was that the owner did not require a change in vessel documentation (the docking plan) when the physical aspect of the change order merited the alteration in the plan.

## Rights: 1

One of the considerations that has to be addressed during ship design and ship construction is that of intellectual property rights ('IP'). Simply, it is necessary to identify which party owns the rights to the new design of the ship, or the system, or the component.

An example of the failure to address this issue during contract formation involves the construction of four sister vessels for a company that operates vessels but also possesses its own shipyard. When the owner was going to dock the second of the four vessels for its first dry docking at an independent shipyard, the owner asked the shipbuilder to send the docking plans unique to vessel No. 2 to that independent shipyard. The shipbuilder responded that the owner could use the IP of the docking plans only at the owner's shipyard or the builder's shipyard, but not at any independent shipyard. Why? The docking plans are part of the IP package, said the builder, and the contract did not grant the owner/purchaser IP rights. The owner then had to negotiate to purchase the IP rights, providing the builder with a nice bonus.

## Rights: 2

Contracts for vessel construction often give the shipbuilder the opportunity to present alternate brand names for equipment that the owner initially nominated to come from a different manufacturer. In such instances, the owner contractually reserves the right to reject the shipyard-selected vendor on the basis that the offered equipment is not 'equivalent' to the owner-nominated one.

The rejection cannot appear to be arbitrary without creating disputes because it may look like the owner never intended to accept an alternate, or that a back-deal has been made. Instead, during contract formation, the owner has to identify the parameters or characteristics that will be considered to determine the question of equivalency: material content, availability of spares or tech reps, weight, noise and vibration, power consumption, language of manuals, mean time between failures, place of manufacturing, etc.

## Place of delivery

Not all spare parts are kept aboard a vessel given that those spares might serve any of several sister vessels. When a shipyard is procuring spares and supplies for an owner, the owner's team should specify the location of delivery of those materials. Possible choices are: (a) shipyard warehouse; (b) dockside; (c) ship's deck; (d) stowed aboard the vessel in designated lockers or spaces; or (e) owner's off-premises warehouse. That is, the owner's team has to investigate these issues before completing the specifications.

This can become an issue when the item in question is owner-furnished equipment ('OFE') being delivered to the shipyard. The place and time of delivery has to be specified, such as at the shipyard's warehouse or dock. If that is specified, the shipyard should resist doing a 'good deed' by taking delivery at some location other than that identified in the contract. A further possible issue: is OFE considered delivered when it passes through the shipyard gate, or does it have to undergo an owner's incoming materials inspection before it is officially delivered to the shipyard? Word of advice to shipyards: do not accept OFE unless you are satisfied that it is being delivered to the shipyard in installable condition or in the condition described in the contract specifications.

## About the author

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# Accelerated Concept Design

C-Job Naval Architects has implemented a new holistic method to optimise ship designs, which allows for quick design iterations and innovations, as well as saving the naval architect time, writes Roy de Winter

C-Job Naval Architects is the largest independent ship design and engineering company in the Netherlands. The company employs over 130 in-house maritime engineers and naval architects in four offices, and specialises in sectors including dredging, heavy lift, offshore (wind), ferries and superyachts. From the first concept vessel design, through the basic and detailed engineering packages, C-Job's naval architects aim to produce innovative and sustainable solutions for the global maritime industry.

In the concept design phase, new vessels come to light, combining an initial idea from a client with ideas from the naval architect. The decisions made at this design stage are crucial since they will define the future performance of the vessel. These decisions mostly deal with the general arrangement, hull form, geometry, and compartmentation of the design. All decisions at this stage affect each other and early choices can lead to constraints in later phases.

It would be interesting to be able to postpone decisions or make decisions in such a manner that they could easily be reversed. This way, a lot of different design variations could be generated and compared to each other. Comparing these different design variations then helps the naval architect in choosing the best possible solution, making well founded decisions, and finally it helps the naval architect to draw the optimal ship. At C-Job an approach where decisions can easily be made and reversed has been developed under the name 'Accelerated Concept Design' (ACD).

## The traditional approach

Traditionally, ship designs are optimised in an iterative way using the classical design spiral (see Figure 1). However, this approach is very time consuming and labour intensive. This is because ship designs typically have a lot of decision variables, complex constraints and multiple conflicting objectives. Classic examples of conflicting objectives in ship design are resistance and steel weight. A longer and more slender ship will likely have a higher steel weight and a smaller resistance factor compared to a wider and shorter ship.

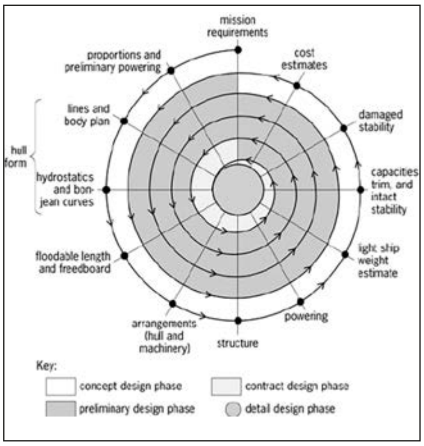


Fig. 1: The traditional design spiral was felt to be inefficient (courtesy J. Harvey Evans)

It is impossible to consider all the possible design variations and dependencies between the decision variables, the constraints, and the objectives. Thus, the traditional approach does not immediately lead to the optimal ship design. Sequential labour-intensive iterations are needed to (possibly) achieve an optimal design.

## The ACD approach

A concept design task can be dealt with much more efficiently than through the traditional iterative approach. Therefore, C-Job has implemented the ACD as a holistic design framework. The novel 'Design Circle' (see Figure 2) allows for quick design iterations, optimisation possibilities and exciting innovations, which would for a naval architect alone be very hard to come up with.

After an initial starting point has been created by the naval architect, the concept design optimisation process can start. A concept design is typically optimised in a way that multiple elements are considered at the same time. These include hull resistance, building costs, stability, and steel weight. The optimisation can be achieved by changing the hull shape, geometry and the compartmentation in such a manner that the regulations and demands from both the classification society and the client are met.

Changing the hull shape, geometry, and compartmentation is undertaken by setting up a concept design in a parametric manner. An example of a parametric concept design could be a concept hull design where the aft-, mid- and foreship can be made longer/shorter and wider/smaller with the help of free form deformation (see Figure 3). On

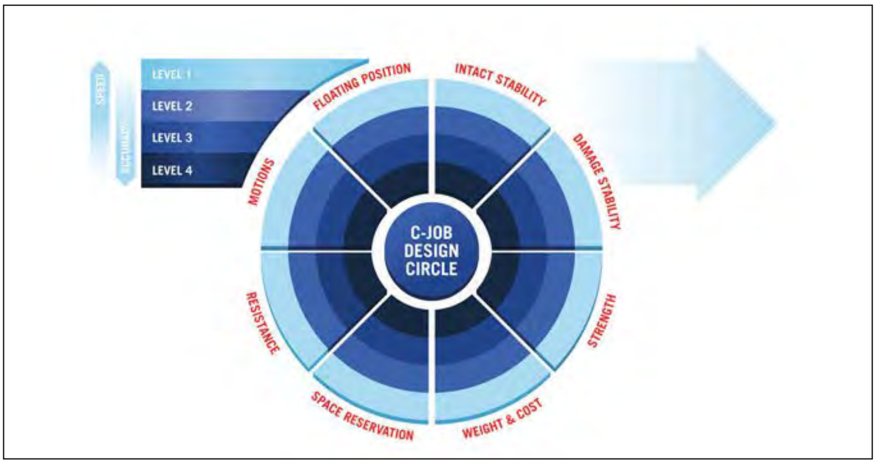


Fig. 2: The 'Design Circle' adopts a more holistic approach to design, considering multiple elements simultaneously

Fig. 3: Parametric concept design for a hull

top of this, the bulkhead locations could be parameterised so that the bulkheads can be moved back and forward, enabling the space capacity for each room to be easily adjusted.

After the whole concept design is parameterised, optimisation can begin in earnest. The ACD framework takes the following components into consideration: floating position, intact stability, damage stability, strength, weight & cost, space reservation, resistance, and motions. The ship components in the ACD framework can be computed using four different levels of accuracy. Components on level 1 are estimated based on the data from similar reference vessels. Components on level 2 are estimated using more advanced statistical regression models. Component scores on level 3 are estimated using simulation software. Often unnecessary in the concept phase is level 4, where the absolute values for each component are estimated to the highest accuracy.

As an example, the four different levels for the resistance factor are given. On level 1, reference data from other similar ships with the same dimensions are used to estimate the resistance. On level 2, the Holtrop and Mennen estimation method is used to estimate the resistance. On level 3, a potential flow solver which simulates the water flow around the ship is used to come to a resistance factor. Finally, the most accurate method to get the resistance would be a full detail CFD (Computational Fluid Dynamics) simulation.

Since every aspect of a ship presented in the design circle is computed simultaneously and automatically, any concept design can be optimised using smart optimisation algorithms; all the promising design variations can be generated automatically and computed by the framework. As such, human time and effort is taken out of the loop and no time-consuming and repetitive work needs to be done.

An algorithm capable of guiding the process and optimising the concept design has been developed by C-Job's data scientist Roy de Winter. In close collaboration with the Leiden Institute of Advanced Computer Science, De Winter developed CEGO (Constrained Efficient Global Optimisation). This algorithm can simultaneously optimise multiple objectives and deal with multiple constraints and decision variables. On top of this, CEGO optimises the concept design using only a limited amount of function evaluations. This is important since some aspects of a design variation can be expensive to compute and only a limited time is available in the concept design stage.

## ACD results

When the optimisation algorithm terminates and the ACD framework has computed a few hundred different design variations, the naval architect can analyse the most promising ones by looking at the solutions that lie on the so-called Pareto frontier (see Figure 4). On the Pareto frontier lie the design variations for which it holds that the design variation cannot be improved in any objective without sacrificing another objective.

Recall the classical example where the naval architect wants to minimise the conflicting objectives of resistance and steel weight. Two solutions which in this case could for example lie on the Pareto frontier would be two ships with the same specifications except for the width, length and the required fuel capacity to sail 20knots. Ship 1 would be a vessel with a steel weight of 10,000tons and a resistance factor of 0.9 while Ship 2 would be a vessel with a steel weight of 8,000tons and a resistance factor of 1.1. If we assume a positive relation between steel weight and building costs, ship 1 would in this case be more expensive to build but cheaper to operate while ship 2 would be cheaper to build but more expensive to operate. Besides finding a trade-off, the framework also creates design variations that are better compared to the initial design. The framework has already proven to be successful, for example creating a ship design with a 19% reduction of resistance while having a 14% lower steel weight compared to the initial design.

In consultation with the client, one of the vessels from the Pareto frontier is chosen. From the chosen design, the general arrangement, hull, geometry and the compartmentation are drawn in more detail and delivered to the client. This way, the effort of smart optimisation algorithms and the experience of the naval architect can be combined to create better vessels in less time. *NA*

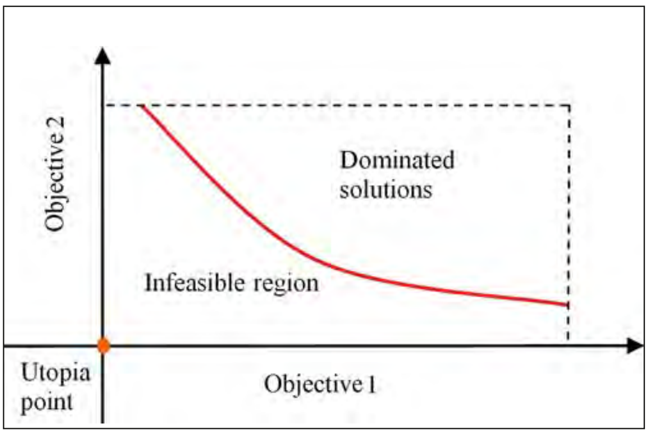


Fig. 4: The Pareto frontier, as applied to design optimisation

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# A bright green approach to electrification

## Young Dutch company Skoon hopes to fast-track the electrification of shipping by developing a network of shareable, containerised batteries

Skoon co-founder Peter Paul van Voorst admits that he never planned to start his own company while studying Maritime Technology at TU Delft. His classmate Daan Geldermans, on the other hand, says that "starting a company was always an ambition." Nonetheless, when Geldermans saw a "somewhat mysterious" social media post by van Voorst hinting at a new venture in maritime sustainability, his curiosity was piqued.

In the pair's subsequent meetings, it became clear that both had struck upon the idea of using containerised energy to save fuel, with van Voorst advocating batteries and Geldermans hydrogen fuel cells. They also shared the desire to bring about the electrification of shipping much more quickly, particularly in light of impending IMO and local emissions regulations. Peter Paul and Daan decided to work together, ultimately settling on batteries due to van Voorst's experience the previous year as a Young Maritime Ambassador, which convinced him of the technology's advantages.


The first Skoonbox was unveiled at World Port Days 2018 in Rotterdam

Speaking to a range of industry figures from captains to CEOs, van Voorst says that everyone recognised "something was coming" to make maritime more sustainable. Although "there were some big companies taking steps," he says, "I looked at the technical options, and realised that battery-electric shipping would be easiest to implement in the short-term." Its key strength, according to van Voorst, is that "battery-electric sailing is that it is so simple. It is easy to understand for anybody."

Although van Voorst was confident of the technical case, with batteries being successfully utilised on ferries, barges and even cargo vessels in recent years, he knew there had to be a business case to match. Applying some creative thinking, van Voorst and Geldermans realised that the highly variable power requirements of different vessels – and other target users including construction sites, festivals, and energy producers – would be best served by swappable containerised batteries. By supplying the amount of power needed by each user as and when, and then reclaiming the battery to be recharged and redistributed, Skoon could produce more value from each unit whilst offering a high degree of flexibility.

The main benefit of containerised energy solutions is the standardisation of the twenty-foot container across industry and the vast logistics network that supports it. Containers are compatible with ports, cranes, trains, trucks, and vessels, meaning they can be transported and handled with ease. In fact, although battery sharing has previously been mooted for the automotive industry, the lack of a standard size unit and infrastructure has prevented projects from progressing.

To underpin the roll-out and uptake of these shareable battery units, dubbed 'Skoonboxes', the pair recognised the need for a physical network of pickup points and charging hubs, supported by a digital network to enable battery tracking, booking and payment in real time. Hoping to make this network a reality and realise the potential of their solution, van Voorst and Geldermans officially established Skoon in Leidschendam in September 2017. The team is now eight-strong.

### Batteries on tap

Batteries are currently undergoing a period of significant development, with multiple companies working on increasing their power capacity and minimising their space requirements. However, the price of batteries remains prohibitively high for many shipowners, with investment deemed too risky.

Van Voorst points out that Skoon's shareable container "takes away the investment needs for shipowners [as] it can be too expensive to own a battery and just be the only user." Moreover, he says, "the ongoing development of batteries is a reason not to invest in batteries yourself. If you buy them today and in two years they are developed to two thirds of the size with the same power, you're stuck with your batteries." Skoon, however, can retain older batteries for appropriate users, whilst offering the latest, most efficient units to others.

Initially, Skoon will use lithium ion batteries due to the maturity of the technology and its known safety status,


Impression of Skoonboxes on board *Borelli* in Rotterdam harbour

meaning less extensive testing, although van Voorst doesn't rule out an eventual switch to different energy sources, including hydrogen, as they become more viable. As for now, van Voorst hints there have been productive talks with a manufacturer that can supply batteries and "scale up with us".

The application of Skoonboxes is to be entirely down to the customer, with some utilising the technology to help power a route from A to B, and others taking on a Skoonbox in port to benefit from cold ironing. Skoonboxes can also complement existing batteries if a period of stormy weather is forecasted, to cope with the increased power demand.

Two payment models will be available, with one based on kilowatt hours and the other on a longer-term lease, in which customers "take it for some weeks or years, and charge the batteries themselves." The only difference, van Voorst explains, "is who puts the energy in the batteries."

When Skoon charges batteries, it will do so with renewable energy purchased directly from the grid in the Netherlands. To save on this significant cost, van Voorst and Geldermans explain that they will take advantage of energy market imbalances, buying "at the low moments when everybody is asleep." To streamline this process, Skoon will use an algorithm that also takes into account the effect of the weather on energy production.

Skoon is now focused on funding and delivering an initial set of Skoonboxes, with the first unveiled in early September at World Port Days in Rotterdam. As speed in both development and uptake is crucial to the concept, the pair remark that they welcome competitors in the market: "As we're scaling up as a company we also want others to invest in these batteries and this market to grow. If 10 vessels have half the battery size they need and the other half comes from us, that's easier for us than if 10 vessels need 100% of their energy from us."

## The Skoon network

Arguably what makes Skoon's offering unique is not the Skoonboxes themselves but rather the sharing infrastructure that will support them. The company hopes to offer a network of charging hubs located throughout Europe and eventually the world, in both coastal and inland waterway locations, from which shipowners can access and return Skoonboxes.

The location of these hubs, explains Geldermans, "will be very close to the ports, if possible at the ports. Transport would only take five to ten minutes, and then cranes would place the Skoonbox on board with the rest of the containers." Since the customer "books a few days in advance, saying 'I need x amount of power', we can make sure the Skoonboxes are ready at the terminal," he says. As well as delivering Skoonboxes at the quayside, Skoon also hopes to use feeder boats to deliver containers directly to vessels to cut out unnecessary docking.

To begin development of its network, the company will first target the Netherlands' inland waterways, with Geldermans highlighting the city of Nijmegen on the Waal (leading to the Rhine). The Port of Rotterdam has also been chosen to enable short-sea routes. Further possibilities include Amsterdam and Antwerp, although Geldermans admits the complexity of planning a network before usage and routing trends can be identified.

Supporting this physical network is a digital one. Skoon customers will book their Skoonboxes though a dedicated app, "a pocket size platform that can book your containers as easily as you order something on eBay or Amazon," claims Geldermans. The app will show location, level of charge, and voltage of each Skoonbox, and once on board, will monitor power use. It is hoped that using a real-time system will allow shipowners to meet their power demands in the most optimal fashion.

## Industry engagement

To fully realise its concept, Skoon has significant financial, logistical and regulatory challenges ahead. However, the company's recent signing of an agreement of understanding with fellow Dutch company Damen (as featured in September's *The Naval Architect*) is set to offer a boost, providing access to Damen's large network of clients and technical expertise. For Damen, which is itself interested in electrification, the agreement offers an agile approach to innovation via a start-up.

Later this year, a 'showcase' of a Skoonbox is planned for the diesel-electric inland container vessel *Borelli*, owned by Netherlands-based The Blue World. According to van Voorst, the trial represents Skoon "showing that it's possible. We want to make people realise this and invite them on board to experience the comfort of full electric sailing." As for The Blue World, van Voorst says that "they see this is the future. It's as if they saw this coming. There are already cable holes at the location where our Skoonbox will be."

Following the 'showcase', next year will see Skoon seeking investment to construct the first tranche of Skoonboxes, as well as developing the initial charging hubs. Despite the uncertainty that comes with being an early stage, disruptive business, what is clear is the drive of van Voorst, Geldermans and their team to make their vision of widespread electrification in shipping a reality. If enough shipowners get on board, bright green boxes might be a familiar sight on board in the years to come. *NA*

# Feeling the way towards haptics in maritime

In conversation with TU Delft researchers, *The Naval Architect* explores how incorporating haptic feedback into vessel controls – and ultimately remote control stations – can improve situational awareness, paving the way towards unmanned vessels


The researchers' test setup features control levers with actuation motors to provide haptic feedback linked to VSTEP bridge simulation software

Our experience of the world around us depends on a plethora of sensory inputs. When one of these inputs is lost, our situational awareness is diminished. This is particularly true of touch; although its value may be harder to describe than sight, it is an essential interface between us and our environment.

Recognition of this fact underscores the broad field of haptics research, and especially haptics technology, which attempts to recreate the sense of touch that has been lost in the transition from direct human-powered control to electrically and hydraulically actuated systems. Most people's experience of haptics is via their smartphone, which incorporate haptic feedback in the form of vibrations, rumbling and clicking to provide a more reactive experience for the user.

Industrial applications in control systems offer greater possibilities and subsequently greater benefits. Incorporating a sense of touch through dampening, resistance and other techniques to reflect changes in the outside environment and vehicle operation is claimed to enhance control ability, improve situational awareness and increase safety. With haptic feedback, users don't need to switch their focus between displays nor rely as heavily on visual cues, which have a coupling time between perception and action 10 times slower than haptics: 200 milliseconds versus 20 milliseconds.

## Haptics in Holland

The Delft Haptics Lab, based at TU Delft and led by Professor David Abbink, has explored haptics in relation to robotics, cars, and aerospace, conducting a number of industry-funded projects. More recently, it has delved into the maritime world as Arthur Vrijdag, assistant professor at the Maritime and Transport Technology department of Delft, recognised the potential of haptics for vessel control systems – particularly in light of developments in remote operation. A recently-concluded cohesion project was soon undertaken to develop a test setup coupling haptic levers featuring actuation motors with VSTEP bridge simulation software. Using a haptic algorithm, different forces and torque can be applied to the motors in the control levers, allowing users to 'feel' the operation of the vessel.

The researchers like to say that "feeling is believing," as "it is difficult to fully appreciate the ideas based on words." However, examples include a control lever feeding back greater resistance as a vessel approaches the quayside, or providing counter-torque to make an operator aware of the actual position of an azimuthing propeller in relation to the position of the lever.

Abbink and Vrijdag are keen to point out that haptics goes beyond attention-grabbing vibrations which act as a warning that a threshold has been exceeded. More subtle types of haptic feedback are preferable because they act in relation to these thresholds. Abbink explains: "We think that the real power is not so much in vibrations, but in low-frequency forces. These can push you back, or make it more difficult to exceed certain operational limits. Feedback is given at the place where action is required, making things very intuitive."

Another benefit of using forces is that they reduce subjectivity, says Abbink: "When you get the advice not to exceed a certain RPM, you have to interpret that advice. But if you feel it is more difficult to move the lever in that direction, it's very easy to understand."

## Out of touch

In order for haptic feedback to reflect vessel operation, various inputs must be measured, filtered and 'presented' to the operator through a haptic algorithm. Whilst the researchers are still perfecting this algorithm, Vrijdag notes that the measurement process does not add much complexity as vessels are replete with sensors: "An incredible amount of sensor data is already being collected, processed and presented to the operator. One could say that for many possible applications of haptic technology onboard, the main sensors are already there, but the haptic levers provide a different way to communicate their outputs to the operator."

In fact, a more significant issue is resistance from mariners who question the necessity of the technology, arguing that vessels can be operated safely without it. To this, Vrijdag retorts that "without haptics, of course you can still do tasks, but just slower with more effort and visual load," thus placing more pressure on the operator. Abbink adds that this response is often grounded in the fear of 'losing one's job to a robot or algorithm'. However, he points out that haptics "really is about co-operation between the human and the algorithm. Haptics frees up brain space to think about what is coming in the future." Despite its technical status, the researchers suggest that haptics actually provide a more natural way to operate a vessel, as it involves the human body in the process.

## Remote operation

The improvement in situational awareness offered by haptics becomes especially desirable in the development of remote operation systems. Many sensory inputs are lost when operators are taken off the vessel, explains Vrijdag: "You take in so much more information from the environment than what you see on displays – ship motions, vibrations, the spray of water on your face. They all give you pieces of information that you put together and say either 'everything is ok' or 'something is wrong and I need to check it out'. You lose all of these things if you are sitting in a control station." Haptics can be applied to mitigate this problem: "We cannot replace all of these cues, but if we can partly put them back, we truly believe this will be powerful. Soft information is far more important than you realise."

In the design of remote operator stations, the pair says that 'multi-sensory integration' should therefore be paramount: "When we design interfaces for humans, quite often we just do the visual sense: displays upon displays. To do this better is important and haptics has a very strong contribution."

With increased distance between the operator and ship/sensor, the problem of latency arises – the delay between an input and output in the form of haptic feedback. However, the idiosyncrasies of maritime render this a minor issue as, in Abbink's words: "A lot of maritime operations revolve around avoiding contact rather than rendering contact." Therefore, small delays in transmission matter less than in 'hard' haptic operations where touch is actively applied.

As for the type of vessels that will benefit most from the incorporation of haptics, Vrijdag admits that this is still an open question. However, he suggests: "The more multifunctional ships are, the more options there are for haptic feedback." Examples include offshore wind MPVs, ASD tugs, and inland vessels, all of which require operators to use levers almost continuously. Vessels of this type have been mooted as candidates for remote operation, exemplified by the demonstration of a remotely controlled Svitzer tug in Copenhagen harbour last year, which was fitted with Rolls-Royce technology.

More generally, haptics will likely aid remote operators piloting ships in port, as vessels of all sizes must be carefully manoeuvred to avoid the multiple and ever-shifting hazards. Therefore, if haptic feedback can deliver on its promise of improving control ability, it may result in an efficiency and safety boost in port settings, especially when coupled with the intelligent awareness systems being developed by the likes of Rolls-Royce Marine (now owned by Kongsberg) and ABB (see p14). For maritime and harbour pilots, haptic technology can also compensate somewhat for ever-more congested ports and growing vessel size.

## Within reach

Having developed their test setup, Vrijdag and Abbink have recently conducted a project looking to reduce impacts on operators of small fast ships in waves, and have provided demonstrations of their levers at numerous maritime events. According to the researchers, several companies have also visited the lab to test the equipment and discuss possible applications.

Vrijdag acknowledges that the technology remains at a low readiness level. However, the researchers hope to use their levers with a full-size bridge simulator soon, involving third-party users to gain feedback and improve the system, particularly the algorithm. Ultimately, their goal is to work in full-scale in a safe zone or port and undertake a proof-of-concept both on board and remotely.

Initial reactions in a simulated environment, they say, have been positive, and often joyful: "When they feel what it's like when they have it, you see their eyes light up!" Whether haptics delivers in full-scale remains to be seen, and this is paired with the task of convincing an often-sceptical industry. Regardless, Abbink insists that one conclusion can be drawn with confidence: "Maybe haptics isn't necessary, but it sure helps!" *NA*

David Abbink and Arthur Vrijdag are working together to explore haptics in maritime


# Taking passenger ship evacuation to a safer place

## Viking Life-Saving Equipment speaks to *The Naval Architect* about the benefits of expert consultation when it comes to arrangements

The perception of many naval architects is that a ship's safety needs translates into its structural requirements. Consequently issues such as the effective evacuation of a vessel, and ensuring that evacuation points are optimally placed, may be treated as something of an afterthought during the design stages. This would be a concern on a merchant ship but for cruise ships or ro-paxes, where passengers may be elderly or have restricted mobility, it represents a particular problem.

Danish company Viking Life-Saving Equipment is keen to impress upon ship designers the value of expert advice when it comes to the effective placement of Marine Evacuation Systems (MES).

Viking says flag state approval for its innovative LifeCraft concept is now just around the corner. As the name suggests LifeCraft is a cross between a liferaft and lifeboat and has been designed with larger cruise ships in mind, offering the advantage of compact storage by comparison with conventional lifeboats. Moreover, each LifeCraft can be connected to three other units (each holding up to 200 persons) to create a 'LifeCraft system' capable of evacuating 800 passengers and crew.

*The Naval Architect* spoke to Niels Frænde, Viking's VP Sales, Cruise & LifeCraft, about the kind of practical safety and evacuation advice an equipment manufacturer can provide during the design process.

**Ideally, at what stage during design should naval architects be consulting with Viking (or other )equipment providers about the evacuation planning for vessels?**

The ideal stage is in conjunction with laying out the major life-saving appliances (LSA's, in particular the MES and lifeboats) arrangement. In a traditional arrangement, you need to consider which of the equipment types should be positioned forward, at the centre or aft.

Niels Fraende, Viking Lifesaving Equipment

From a functionality point of view, the MES is usually best located in the centre of the LSA arrangement, because the liferaft part of the MES is likely to be sitting at water level for a certain period of time while passengers and/or crew are being evacuated. Placing the MES forward or aft is likely to see the liferafts take more of a battering. This way, placing it in the middle is also an advantage for the comfort of those waiting in the liferafts for others to come down.

Lifeboats are more flexible, in terms of where they can be launched from, because they are designed to be fully loaded before being lowered into the water. However, for lifeboats too, the forward and aft positions are the most problematic from a safe launch point of view. That said, both MES and lifeboat systems can, in fact, be located freely wherever on the vessel they are needed – there are no [SOLAS] restrictions on placement.

The Viking LifeCraft can take any position along the deck, as it is motorised, enabling repositioning once in the water, and because it has a fully intelligent list and trim system to enable it to adjust to the ship's own degree of list and trim in an emergency.

**Typically, how can a vessel's operational profile impact in terms of the regulations/ requirements for evacuation?**

Generally speaking, the vessel's operational profile doesn't have a great influence on regulations/requirements for evacuation because these are guided by clear rules governing the types of equipment demanded and the combinations of different equipment types. These rules are, of course, important to consider in their entirety in relation to an LSA arrangement. As a supplier, we work very closely with naval architects to determine the optimal way to answer both regulatory and functional requirements.

That said, there will be some preferences that impact upon LSA designs. For example, international ferries with a short course of call are likely to want to keep the number of lifeboats on board to a minimum, avoiding overhang and reducing the need to conduct drills. Vessels on longer voyages have longer ports of call and therefore more time to perform the necessary drills.

**What are the common areas of confusion you encounter with ship designers when it comes to evacuation systems?**

There are many regulations that affect onboard evacuation systems. A lot of consideration must be given to the percentages of the different equipment types on board, for example. As ships become larger and longer, with more passengers, more equipment is needed and a longer area is required along the ship's side for evacuation.

This, in turn, leads to greater impact in terms of list and trim – and the rules and calculations for this aspect can become very complicated. You need to execute a lot of calculations to work out whether the LSA arrangement will work at, for example, 20° of list and 10° of trim, keeping equipment as low as possible to the water, naturally, but still being able to keep it away from green seas.

Part of the entire equation is the provision of good drop zones for LSA equipment. Then there's the float-free aspect, making sure that

Four LifeCraft units can be connected to hold up to 800 passengers

float-free functionality isn't hampered by balconies or caught under the deck if the ship is sinking. Here we have to work intensively to ensure regulations are followed and that we've worked through all the possible scenarios. Viking has specialised knowledge and vast experience in this area, so it's useful for us to partner up as early as possible to help determine what is correct and optimal.

**How long has Viking been developing the LifeCraft concept?**
Work began in 2009. When you want to do something that challenges the status quo, challenges regulations and everything else, you need to have a very extensive and thorough development process, allowing you to test every aspect intensively. Over the years, we've built and tested more than 50 complete prototypes of the craft, and we're now at the final version – the third generation of the design.

Because we're developing outside of the SOLAS regulations, we need to be immensely thorough in our approach, perhaps even more so once the design is ready to work with the classification and flag processes.

**One of the promoted advantages of LifeCraft is its compactness. How much space can be saved compared to traditional lifeboat/raft/MES solutions?**
When you consider the passenger capacity of the Viking LifeCraft, the required length along the shipside for the equivalent capacity is around 30% less, and on big ships, you're often running out of room along the side. When it comes to sheer deck space, the savings amount to no less than 85% when compared to a traditional setup!

While the extra space can certainly be used for additional cabins, it seems operators are even more keen and focused on utilising the safety gains offered by a LifeCraft based system. Also, some cruise operators would even like to have the idea of a promenade deck back, enabling the offering of different concepts and space for relaxation for the passengers.

**Has LifeCraft received official approval?**
We have finalised harbour and several high-seas tests along with other trials on the LifeCraft unit and submitted test documentation, so the Viking LifeCraft unit is soon expected to get flag approval with its first flag state.

**LifeCraft has been developed with cruise ships in mind – could it also be used on polar expedition ships?**
In its first versions, the VIKING LifeCraft is not aimed at polar vessels. From an operating temperature standpoint, however, nothing prevents the craft from going polar (up to the PC 6 designation). That said, using the LifeCraft for polar expedition ships is not likely as these are normally smaller vessels and the LifeCraft has an 800-person capacity (so there needs to be 1,600 people or more on the ship before it really makes sense).

**How much interest has there been in LifeCraft so far?**
Whenever something truly new appears on the scene and offers completely new standards of safety then it quickly captures the attention of flag states, classification societies, shipyards, vessel operators and so on. The Viking LifeCraft is no different – we're receiving plenty of interest and enquiries from all of the large cruise lines and others whose ships could be suited to this new type of craft. Some of these enquiries are more serious than others, as there are always trendsetters in the industry – and they are currently exploring the details with our technical experts. Following industry practice, we can't name these operators or discuss specific installation plans.

Fuelling this strong level of interest is the lively debate around lifeboat safety. With boats carrying up to 460 people these days, and accidents continuing to occur (though at a lower level than before the recent Lifeboat Release and Retrieval System (LRSS) regulatory update), alternative evacuation systems have become a hot topic.

Alongside the safety issue there are a number of practical aspects that are seeing some shipowners and operators trying to reduce the number of lifeboats onboard. For example, vessels passing through the new Panama Canal need to minimise overhang. And this overhang, typically two to three metres on either side, is also a potential problem that affects port operations, too.

The Viking LifeCraft answers a long list of such issues, and it certainly provides a slicker design for the ship's side! *NA*
**www.viking-life.com**

The LifeCraft can be compactly stored beside the deck

# Survitec Group launches SOLAS 360

## The equipment manufacturer's holistic solution can ensure shipowners stay ahead of the curve, says Terje Borkenhagen, VP Sales, Marine & Offshore

The shipbuilding industry has come under some strain following recent profit warnings and labour force reduction concerns. But if the tide is to turn, one thing the sector cannot abandon is its commitment to both pre-emptive and solution-oriented safety measures.

Safety manufacturers have an important role to play, working in conjunction with engineers and procurement teams to not only provide equipment for newbuild projects, but to ensure safety solutions are prioritised from the outset.

Retrofit equipment to a vessel has certain merits and allows for updates, but focussing on safety during the construction process is a preventative measure that allows for greater integration.

With this in mind, Survitec has devised the SOLAS 360 concept with the premise of keeping customers safe and compliant, by simplifying safety for a range of products and services including lifeboats, liferafts, personal lifesaving appliances, fire detection, protection and extinction systems. Survitec's network has made this possible, with eight manufacturing locations, 15 offshore support centres globally, more than 70 owned service centres worldwide, and over 500 third-party facilities covering 2,000 ports.

SOLAS 360 maps the requirements and managing services on all safety equipment. This in turn reduces the element of risk and helps operators purchase the most up-to-date technical specification products and services. Also included is a 'service completion guarantee', both before and after construction, that monitors a vessel's due dates, proactively scheduling servicing and ensuring that the job is done before certificates expire. An online 'Safety Portal' provides visibility of each vessel's compliancy status and safety certificates. Survitec can also visit vessels and create a detailed plan for all service and replacement needs after an initial onboard inspection.

SOLAS 360 launched in full at SMM in Germany. Survitec is confident there is appetite from the maritime market for a safety solution that reduces the administrative burden on procurement teams, by offering products and services through one supplier. *NA*

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# Developing a 3D model-based design approval viewer

The Korean Register has developed an efficient, secure system for the exchange of large format drawings


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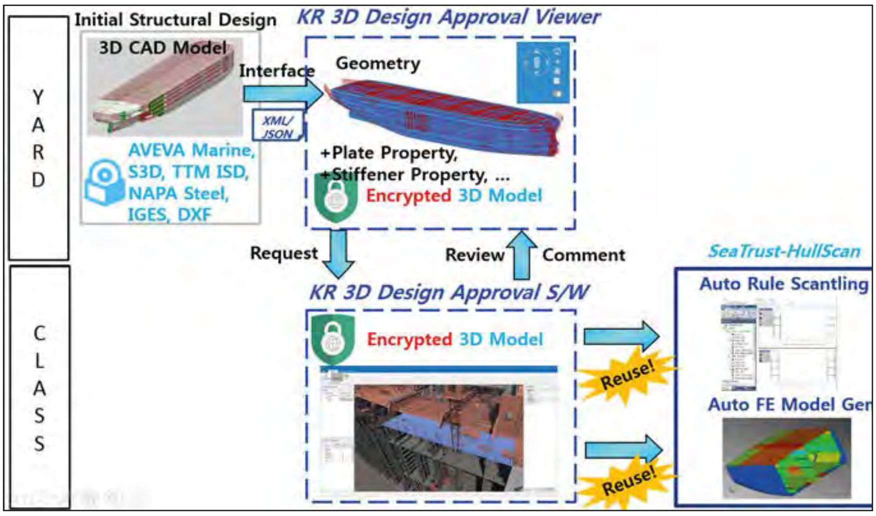


Fig. 1 Overview of KR's 3D model-based design approval system

Traditionally, the design approval of a ship by a classification society has been a paper-based process, involving the exchange of numerous large-format drawings between the shipyard and the classification society. However, Korean Register (KR), an IACS classification society, has developed a 3D model-based design approval system to manage this process more efficiently and securely, which is now being rolled out to all customers involved in this process.

It used to be the case that any plans and documents showing the details of the construction, materials, scantlings and the particulars of a ship's hull, equipment and machinery needed to be submitted in triplicate and approved before the work was started. Now, all of the many 2D drawings are shared between the shipyards and KR using the electric drawing approval system. The drawings are transferred in compatible electronic formats such as PDF using data encryption, to pass them easily and safely between both parties.

Today, the model paradigm in ship design has shifted from 2D drawing to 3D modelling for the initial design phase in Korean major shipyards (Son et al., 2016). As a result, the model paradigm of KR's bespoke structural assessment software SeaTrust-HullScan, which supports both the rule scantling and direct strength assessment has also moved from 2D geometry and 3D finite element modelling to 3D geometry and 3D finite element modelling to take advantage of the 3D CAD (Computer-Aided Design) model of the whole ship that has been created and used in the initial design phase (Son et al., 2017).

KR has developed the interfaces in the SeaTrust-HullScan software to include all the structural CAD (AVEVA Marine, Intergraph S3D, NAPA Steel, and TTM ISD) which are used in the initial shipbuilding structural design divisions in the Korean shipyards.

KR has been working to develop this 3D model-based design approval system since 2017, all with the aim of supporting enhanced productivity in the shipyards and providing a more accurate and intuitive review of ship structure for the classification societies.

## Outline of 3D Model-based Design Approval System

The outline of 3D model-based design approval system is shown in Fig.1. It comprises two main software viewers for the 3D model of a whole ship. The functional requirements for these viewers were developed following discussions with shipyard design engineers, who were familiar with the 3D model in the initial design phase, plan approval surveyors and 3D-based engineering software developers. Their requirements were as follows:

- 3D viewer basic handling (zoom, pan, clip, rotate, selected entity)
- Dimension, area and volume measurement
- Management for approval zone/ item/ part
- Historical management for approval/ revision part
- 3D model-related comment/ annotation
- Effective SeaTrust-HullScan Interface

The viewer does not support the creation of any geometry for the ship hull structure, only providing an effective interface with the shipbuilding 3D CAD system. For this CAD interface, each 3D CAD system presents its own neutral format (XML; eXtensible Mark-up Language)-based 3D model definition for the ship structure. As a result, the neutral format containing the information

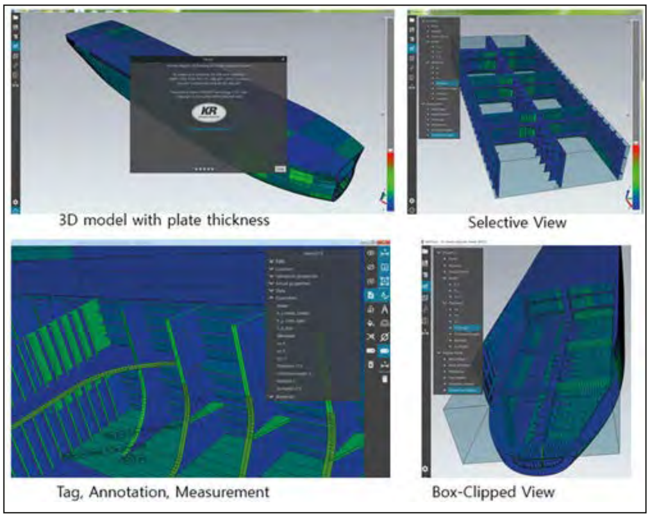


Fig. 2 Overview of 3D model-based design approval viewer


Fig. 3 the advanced section view functionality

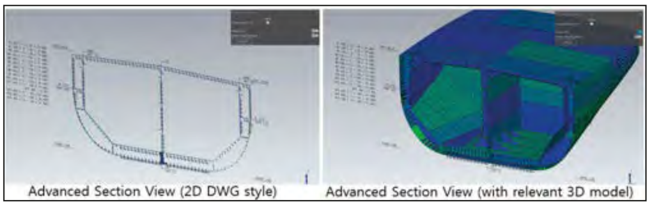


Fig. 4 Multiple platforms supporting the same 3D model

necessary for the plan approval of the 3D ship model of the initial structure CAD, which is used in the shipyard, needs to be created first.

The shipyard requires a viewer that can convert and validate the 3D model into a neutral format. It is important for the shipyard to see the conversion of the model through this viewer, and the neutral format means that all information is released, with the viewer also controlling the encryption of the model and file size.

The same viewer is available to the plan approval surveyor in the classification society; it includes features that enable plan approval to be performed effectively, while supporting the calculation functions, and providing the necessary engineering software.

The encrypted 3D model file for the design approval must be registered and managed through the electronic plan approval system. The design approval system must also act as the interface for the 3D model in the viewer, allowing the verification of rule scantling and direct strength analysis using SeaTrust-HullScan.

## The major features of the 3D design approval viewer

The main part of the system is the 3D model-based design approval viewer that handles the whole-ship 3D model, giving a fast response for 3D model handling. The 3D viewer supports not only the 3D geometries of the ship but also gives the properties of the structural members such as the plate and stiffeners including their thickness, size, type, and material.

Fig. 2 shows the general functionality of the viewer. The various structural member properties and associated information are presented visually with the model and also displayed in an information window. The whole ship model can be seen at a glance, and also supports various selective methods such as min-max box clipping, three plane clipping, showing only a selected object, or defining the zone that user wants to see to examine internal structures in detail or to conduct a structural review for a specific cargo hold area.

In addition to the basic functions for handling the 3D model, the system also supports the specific functions for the 3D model design approval viewer. Tag information linked to objects in each model can be added and modified and annotation can be created, modified and managed. In addition, the measurement function allows users to see the distance and angle between each structural member.

The advanced section view functionality has been developed for surveyors from the classification society who are not familiar with 3D model. It presents the conventional 2D drawing style view using the 3D model, allowing the user to check specific details, as shown in Fig. 3. The user can view the longitudinal direction of the whole ship model, changing the desired position freely and whenever he/she presses the calculation button to check the cross section, a 2D drawing-style view is generated in real time for that position.

The generated information is expressed in text, giving the major locations of the main structure members, the spacing between each member, and the size of the stiffeners. These objects can be moved and arranged to any working space position, allowing the screen-captured view to be used as a rough drawing.

The benefits of the 3D model can be found in the right-hand side of Fig. 3.

Providing the 2D drawing style view alongside the relevant 3D models gives an easy understanding of the continuous and corresponding structural members related to the specific frame position.

Unlike the 2D drawing, this model can then be viewed by rotating, magnifying, selecting objects, with the optional graphical representations for various member properties.

## Further developments

In August 2018, KR developed a 3D model-based design approval viewer which supports multiple platforms such as PC (MS Windows, linux) or mobile devices such as tablet or smartphone (Android, iOS) as shown in Fig. 4. This means that the same 3D model and

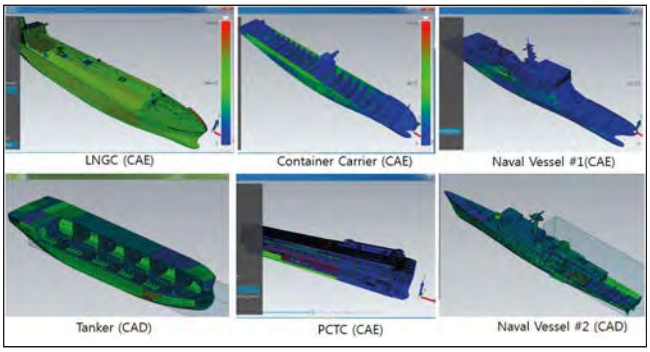


Fig. 5 Various type of ships in the 3D model-based approval viewer

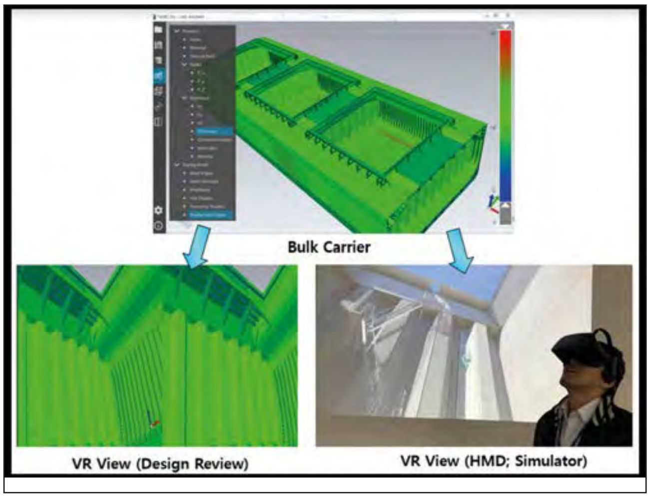


Fig. 6 Extending the 3D model using virtual reality

corresponding comments from the plan approval surveyor can now be accessed on the mobile devices of the field surveyors in the shipyard. In addition, the 3D model, its associated information and engineering data can now be managed through the ship's lifecycle as the digital twin. A web browser-based 3D model viewer is now under development, which will allow the 3D model to be shared without requiring a file transfer, thereby protecting the customer's intellectual property.

Different types of vessels in different types of database for engineering and design (CAE; Computer-Aided Engineering, CAD) have been tested in the viewer as shown in Fig. 5, including an 180,000dwt LNG Carrier with CAE model (Coarse-mesh, fine-mesh, fatigue-mesh with their CAE results), a 13,000 TEU Container Carrier with CAE model (Girder-sized mesh with yield assessment result), a PCTC with CAE model (longi. sized coarse mesh model with yield assessment result), and various naval vessels with CAE models and results.

The viewer supports the CAE result review functionality, giving the design engineer access to more comprehensive engineering data (Son et al., 2018). KR's engineers have also developed an Aframax tanker and various naval vessels as 3D models, using the actual 2D structure drawings and initial structure 3D CAD system to test the viewer in the development stages.

In addition, the lightweight whole ship 3D model can be used to review the design using a VR (virtual reality) environment applying stereographic output, and some touch-up such as texturing and lightening for the VR rendering. The model can also be transferred for further analysis using the VR simulation ship model.

## Conclusion and future work

Today, 3D modelling is being applied and used at all stages of shipbuilding design, resulting in improved processes and more efficient task completion.

KR has widely researched new 3D-model-centric engineering software, resulting in the development of the 3D model-based design approval system. The 3D model should be applied to all parts of the design phase, with the whole ship 3D model offering real-time quick response handling. This article introduces the 3D model-based design approval viewer that satisfies these functional requirements, delivering for the first time a digital twin of a ship.

Using the 3D model-based viewer, KR plans to develop further user-friendly functions for design approval in the future, focused on shortening design approval time, providing more detail and comprehensive reviews of the hull structure members to enhance safety. It is expected that this technology will in time make the digital twin of a ship commonplace across the maritime industry. *NA*

## Acknowledgements

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'In shipbuilding design, 3D Development and commercialization of safety education, training VR contents of sailor using virtual reality technology' project funded by Ministry of Science and ICT of Korea (No. S0602-17-1016).

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# A global R&D hub for advanced safety studies

Prof Jeom Kee Paik introduces the research activities and test facilities of the International Centre for Advanced Safety Studies at KOSORI, which focus on improving the safety of structures in VUCA environments

Ships and offshore structures are often subjected to extreme conditions and accidents while in service. Despite significant efforts at prevention, collisions, grounding, fires, and explosions inevitably occur, leading to catastrophes that can affect personnel, assets and the environment. Such catastrophes are the result of volatility, uncertainty, complexity and ambiguity (VUCA). Actions and the action effects of structures under extreme conditions and accidents are inevitably highly nonlinear and non-Gaussian, involving multiple physical processes, multiple scales and multiple criteria.

It is not possible to represent VUCA environments with only a few scenarios; rather, a full set of event scenarios are carefully selected on the basis of probabilistic characterisation of random variables affecting accidental events. It is now generally recognised that technologies for quantitative risk assessment and management are the best way to effectively manage VUCA environments, and eventually resolve their challenges. Multidisciplinary approaches that take advantage of both advanced computational modelling and large-scale physical model testing are required.

The objective of the International Centre for Advanced Safety Studies (ICASS) at the Korea Ship and Offshore Research Institute (KOSORI), therefore, is to play a leading global role in enhancing the safety of structures and infrastructures against extreme conditions and accidents, and thus mitigate the catastrophic consequences of accidents.

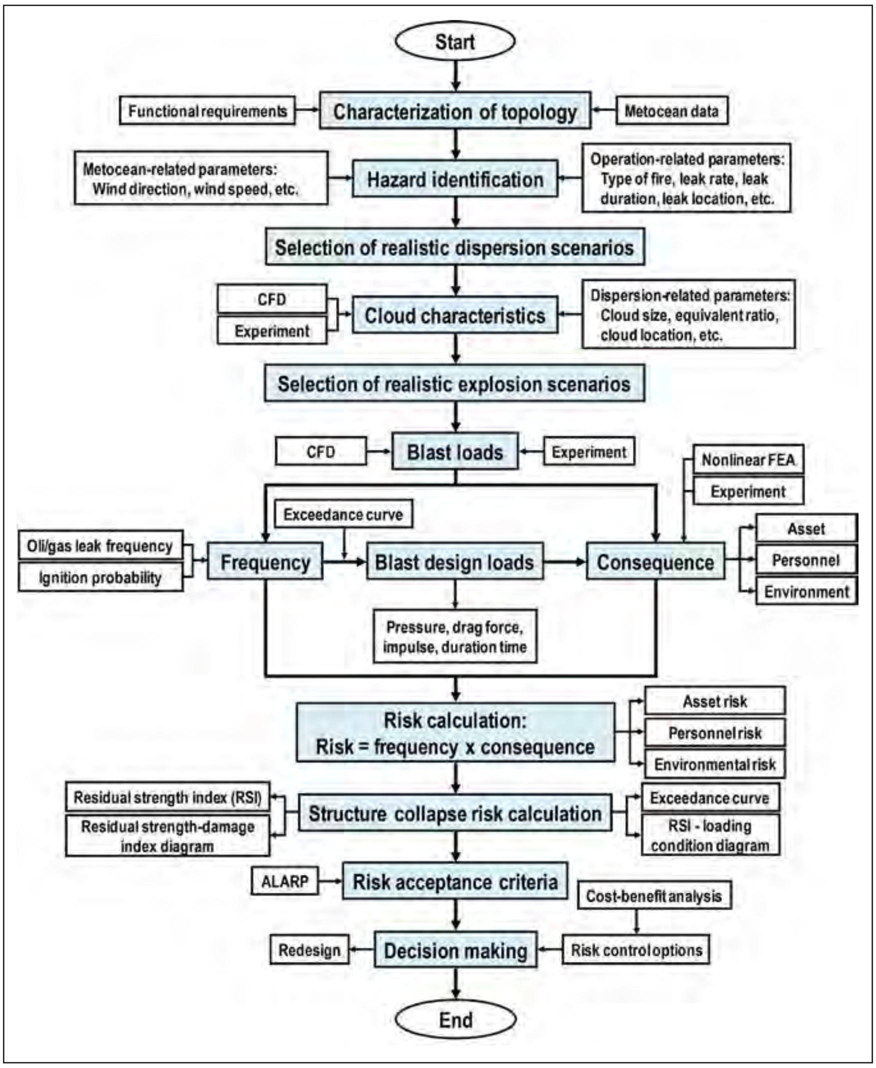


Figure 1. ICASS procedure for quantitative risk assessment and management of structures and infrastructures at explosions

## Frequency and consequence

In the engineering community, risk is defined as a product of frequency and consequence. This is shown in Figure 1, an example of an ICASS procedure for quantitative risk assessment and management, in this case for explosions. While frequency can be calculated using a large database of historical statistics regarding accidents (such as the European Marine Casualty Information Platform [EMCIP]), consequences are determined by advanced computational models and large-scale physical model tests.

Computational fluid dynamics methods are useful for determining action characteristics, and nonlinear finite element methods are now commonly used to compute structural crashworthiness associated with geometric and material nonlinearities involving buckling, plasticity, crushing and fracture. A variety of advanced computational models have been developed in association with ICASS research programmes funded by the Lloyd's Register

Figure 2. Dropped object test facility

Foundation. These include models for the selection of realistic scenarios, frequency calculation, determination of action characteristics, simulation of action effects and structural crashworthiness, calculation of risks (personnel, assets and the environment), establishment of exceedance curves, definition of risk acceptance criteria, and planning of risk management options.

However, computational models are not sufficient to ensure accurate results; large-scale physical model testing is essential to validate them and to identify the complex response characteristics and action effects of structures under extreme and accidental conditions.

In 1638, Galileo said these words about scaling laws: "If the size of a body be diminished, the strength of that body is not diminished in the same proportion; indeed the smaller the body the greater its relative strength. Thus, a small dog could probably carry on his back two or three dogs of his own size, but I believe that a horse could not carry even one of his own size."

In reality, as no adequate scaling laws are available to convert from small scale model test results to full-scale structure responses under extreme conditions and accidents, testing should be undertaken on full- or large-scale structure models, which can then be combined with advanced computational models.

## Test facilities

For this purpose, ICASS has built large-scale physical model test facilities on 23.1ha of land in Hadong, South Korea, with the financial support of central and local governments. Using these facilities, ICASS is dedicated to the development of a test database of large-scale structural models subjected to extreme and accidental conditions. External institutes and organisations are also welcome to make use of the facilities.

Figures 2 and 3 present selected test KOSORI facilities, which allow experimentation on full/large-scale physical models. A complete list of test facilities follows below, and each facility's full performance and functional capabilities can be accessed at www.kosori.org or www.icass.center.

**High Speed Impact Test Facility**. Large ships and offshore structures are composed of steel plate panels with a thickness of over 20mm. The mechanical properties of steel are characterised by a tensile coupon test. An impact test is used to characterise strain rate effects at high-speed loading conditions due to collisions or explosions. Traditionally, tensile coupon testing of material has been undertaken with unrealistically thin test specimens (e.g., with 1mm thick), and it has been presumed that the test results obtained from such specimens are applicable to thick materials. This assumption is serviceable for quasi-static loading conditions, but it is invalid for high speed or impact loading conditions. This test facility can deal with tensile coupon test specimens with a thickness of up to 20mm at a maximum loading speed of 25m/s. The effects of low temperatures and cryogenic conditions can also be treated using a temperature chamber.

**Full-/Large-Scale Structural Failure Test Facility**. Ships and offshore structures under extreme loads show highly nonlinear behaviour until and after the ultimate strength is reached. Not only buckling and plasticity, but also crushing and fracture occur. Small-scale structural models are inadequate for examining the true responses of structural crashworthiness because no relevant scaling laws are available (for many reasons, including fabrications, initial imperfections, and other nonlinear effects). This test facility aims to test full- or large-scale structure models, by allowing application of up to 30MN in force. The effects of low temperatures can also be treated in association with Arctic operation. Test programmes examining full-scale stiffened plate structure models of a 22,000 TEU containership under uniaxial or biaxial compressive loading and 1/6 scaled hull girder structure models of an 1,900 TEU containership under vertical bending moments or combined vertical bending and torsional moments are now being undertaken using this test facility.

**Dropped Object Test Facility**. Ships and offshore structures are often subjected to impact loads due to collisions or dropped objects. In Arctic operation or with LNG cargo systems, they may also be subjected to low temperatures or cryogenic conditions. In this situation, the structures show nonlinear behaviour involving brittle fracture, together with high strain rate effects. Structures at elevated temperatures due to fires may also be subjected to impact loading, again showing highly nonlinear structural responses. Full- or large-scale models can be used to capture the true responses of structures under impact loading.

**Hyperbaric Pressure Test Facility**. Subsea equipment and tubular members (e.g., risers or pipelines) used for developing offshore oil and gas in deep water or for deep sea mining are subjected to ultra-high pressure loads. The size of this hyperbaric test chamber is 1.8m in diameter and 4m deep, and thus full-scale or very large-scale models can be tested directly. The maximum pressure applied is 825bar, which is equivalent to 8,250m water depth.

**Vertical and Horizontal Furnace Test Facility**. In this fire test facility, the increase of temperatures and fire energy (heat flux) can be controlled. Fire dynamics differ from structural positioning, as they are associated with conduction, convection and radiation. Two types of furnace are available, vertical and horizontal. The fire resistance of walls, doors and windows can be tested on full-scale models.

**Fire Collapse Test Facility**. In fires, structures are vulnerable to system collapse, because elevated temperatures significantly reduce the mechanical properties of material, while external forces still continue to apply. This test facility can deal with large-scale structure models at elevated temperatures due to fires and under external compressive forces that cause buckling collapse.

**Indoor Jet/Pool Fire Test Facility.** Jet or pool fire is the most frequent type of fire in industrial production. This indoor fire test facility is used to examine the structural failure characteristics associated with jet or pool fires, with or without water spray or deluge systems.

**Outdoor Fire/Explosion Test Facility**. Fire dynamics are significantly affected by environmental conditions such as wind, and by ventilation. It is very difficult to perform fire tests on large structure models inside a building. This test facility is used to examine the time- and space-variant characteristics of fire or explosion actions (loads); elevated temperatures in fires and overpressure loads in explosions can be physically measured. Full- or large-scale physical model testing to examine nonlinear structural consequences in fires or explosions is also performed.

**Blast Wall Test Facility**. Blast walls are commonly used to protect living quarters in ships and offshore structures against explosions. Given the nature of these structures, blast walls should be as light as possible. This test facility is used to examine the blast responses of walls, doors and windows in explosions.

Figure 3. Vertical-type furnace test facility

**Total Integrated Subsea Test Bed**. Offshore installations for producing oil and gas in deep waters or for deep sea mining need to facilitate long pipelines and tie-backs on the ocean floor. It is necessary to assess risk and ensure fluid flow in association with multiphase flows, together with the effects of pressures and temperatures. Doing so is extremely important for the successful performance of gas/liquid separation and prevention of hydrate plug formation. This facility is used to test the total integrated performance of subsea systems, including fluid flows in pipelines and gas/liquid separation.

## KOSORI combination

Considering that structures and infrastructures under extreme conditions and accidents inevitably involve highly nonlinear responses associated with multiple physical processes, multiple scales and multiple criteria, they cannot be fully identified by mathematical algorithms and related computations alone – physical model testing should be undertaken on full- or large-scale structure models, combined with advanced computational models. It is hoped that technologies using this combination at KOSORI will accurately define and mitigate risks facing ships and offshore structures under extreme conditions and accidents, and ultimately contribute to preventing catastrophes under VUCA environments.

## About the author

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# Practical designer-guided hull form optimisation

Making designer-guided hydrodynamic hull form optimisation part of the design process ensures it will be system-ready and benchmarked, argues HydroComp's Don MacPherson

Design 'optimisation' can be a two-edged sword. It can achieve substantial beneficial outcomes, but it can also consume design resources in a fruitless hunt for perfection.

In naval architecture, where many disciplines – stability, hydrodynamics, capacity, producibility – all compete in the evolution of a design, design studies will never deliver a singular 'numerically optimum' outcome for any one discipline. Certain disciplines, such as safety of life at sea, will appropriately have priority to others. Depending on how you cast the role of a naval architect, the design priorities also fall on any task that best fulfills the objectives of a client's business plan. The best we can hope for is to get reasonably close to an optimum while not handicapping the other disciplines too much. To do this we must set aside the idea of a single optimum for the task at hand and remember that there is typically a broad area of compromise options that achieve close to optimum outcomes. It is in this very messy sandbox (and I love its messiness, by the way) that we approach hydrodynamic hull form optimisation.

Of course, we must remember the primary objective of the optimisation, which in most cases is to achieve minimum fuel consumption. One must model the 'Vessel-Propulsor-Drive' (VPD) system and then fit any component optimisation into this system. HydroComp's NavCad software is at the forefront for this type of hydrodynamic and propulsion system simulation, and also a powerful tool for optimisation of the system's components. NavCad has long been known for its propeller system matching that solves for optimum propeller characteristics, but perhaps less known is that NavCad is also an effective platform for hull form optimisation.

As noted, the objective function of a VPD system optimisation should rightly be minimum fuel consumption, so a comprehensive hull form optimisation would typically include a search for improvements in Vessel-Propulsor interaction. However, a more limited focus on reduction in vessel hull form resistance can be extremely valuable, as it will directly relate to a reduction in the Propulsor-Drive thrust requirement and corresponding fuel consumption. In fact, it is fair to say that a majority of research on 'hull form optimisation' is related to drag reduction.

## 'Designer-guided' optimisation

While there are a variety of iterative high-order approaches and techniques available for an automated optimisation, the need to juggle the various disciplines does not always allow for the 'optimum' hull to actually be used in service (if it did, all hulls would be long and slender with pointy ends). We therefore propose that 'designer-guided' optimisation is necessary to achieve a deliverable pragmatic compromise solution. Of course, a designer-guided solution can then be refined as justified. Analysis with higher-order codes or model testing can follow to further improve the hull using the knowledge gained in the designer-guided investigations.

## Principal parameter optimisation

Some of the biggest improvements in hull form resistance can be achieved by understanding the influence of the significant hydrodynamic parameters. A ship's resistance in different speed regimes will be affected by parameters in different ways. A great example of this is an immersed transom. At low speeds, the water wants to be rejoined easily at the stern, so a transom with substantial immersed section area is detrimental. On the other hand, a transom that promotes clean separation is greatly beneficial at high speeds. Similar influences can be evaluated for center of gravity and entrance angle, for example.

To put this into an appropriate 'energy value' perspective (that better models total power and fuel use), NavCad uses a weighted energy analysis for two operational speeds. It then runs a comparative matrix of significant parameters, ranks their influence, and presents a summary to the naval architect. This provides initial design guidance for where drag reduction might be found – if it is compatible with the requirements of the other design disciplines (see Figure 1).

## Hull form wave-making optimisation

Hull form resistance can be simplified into two general parts – viscous and wave-making. Put another way, it is made up of a frictional drag related to the surface and boundary layer properties, plus the resistance caused by the movement of the water's mass around the ship. Depending on the speed range and characteristics of the


Figure 1 – Drag reduction by parametric assessment

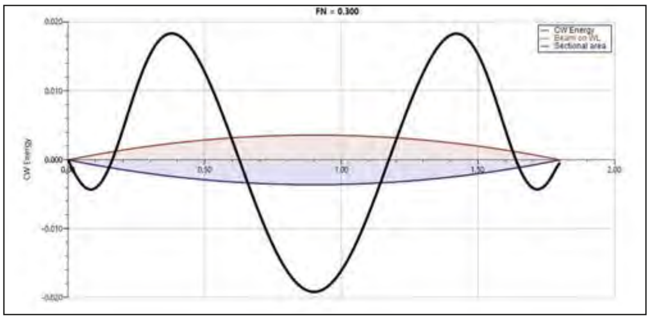


Figure 2 – Longitudinal contribution to wave-making energy (FN=0.30)

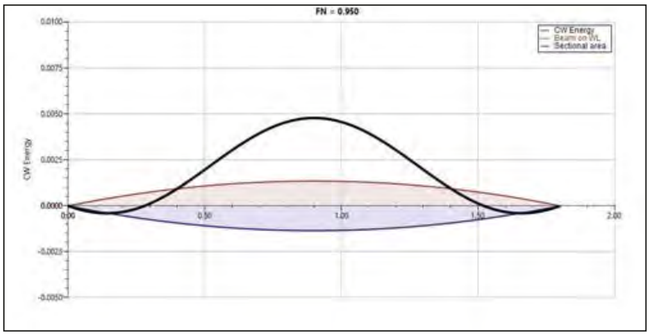


Figure 3 – High speed wave energy plot (FN=0.95)

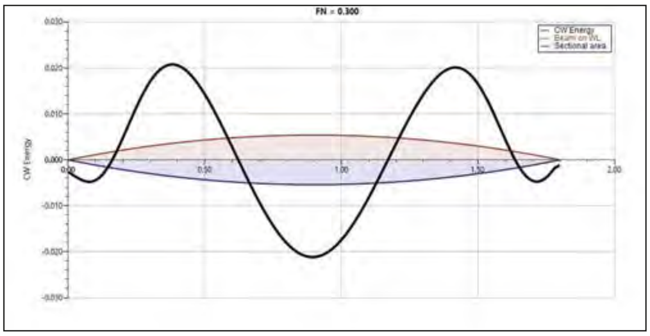


Figure 4 – Minimal viscous influence at moderate speeds

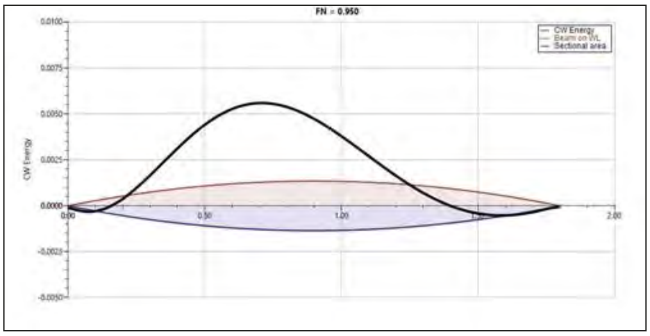


Figure 5 – Substantial viscous influence at high speeds

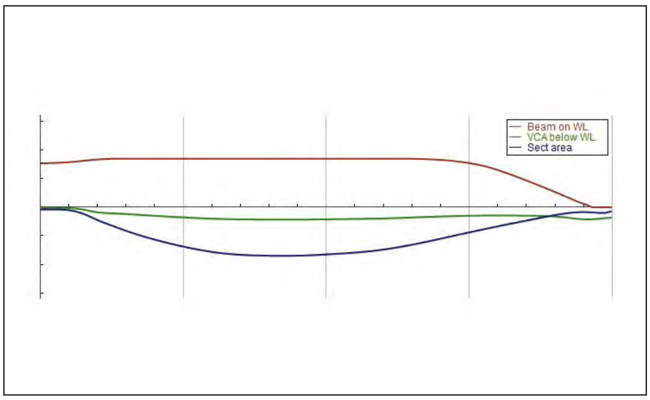


Figure 6 – RoPax distribution of immersed volume for ADVM calculation

ship, the relative proportion of these two parts of total resistance can vary greatly. The resistance of slow ships will tend to be mostly viscous, so hull form improvements typically are about reducing wetted surface area (as producibility and other disciplines allow). Fast ships, on the other hand, demonstrate predominantly wave-making drag, so the hunt for drag reduction is successful when smoothing the path of the water around the ship and past a transom.

All prediction solutions for wave-making drag (including model testing and panel or grid-based codes) provide a computation of the total wave-making resistance. Designer-guided optimisation can now employ a practical means of design feedback about how the longitudinal distribution of hull shape influences wave-making resistance. The foundation of this feedback is found in HydroComp's integration of wave-making drag in the 'Analytical Distributed Volume Method' (ADVM) of NavCad Premium.

## Visualisation of wave-making energy

The analytical prediction of wave-making resistance is based on the Kelvin system of generated transverse and divergent waves. There are many excellent references on this topic so no more will be said here, except that they are systems which reflect the local shape of the immersed volume (such as inflections and shoulders) and go in and out of phase with each other depending on the shape and speed. For example, the following is a plot from NavCad Premium of a symmetric Wigley hull (a very well-known mathematical hull form frequently used for analytical studies) that illustrates the longitudinal phase-based peaks and valleys of the wave-making resistance along the ship's hull. The total wave-making energy is the integration of this curve (Figure 2).

As a ship increases in speed and exceeds the point where the speed-based wave length is longer than the ship's length, the shape of the energy curve will have a principal central hump (Figure 3).

Note that the the plots on Figures 2 and 3 were calculated without a viscous boundary layer shape or sinkage-trim correction. These will alter the magnitude of the wave-making energy and shift the peak aft as shown on Figures 4 and 5.

## Using longitudinal wave energy plots for designer-guided optimisation

The ability to graphically observe the influence of hull shape on wave-making resistance gives naval architects a powerful tool to identify possible problem areas and optimise the hull form.

## RoPax Ferry

In a past article, we described a design study for a 145m RoPax ferry (*The Naval Architect,* January 2018) with the longitudinal distribution of immersed volume as shown on page 39. As described in the article, the predicted resistance of the ship was greater than expected (by comparison to other hulls of comparable size and mission), and the inflection at the stern was considered as a possible source of the added resistance (Figure 6).

Using the most recent ADVM prediction method update, the longitudinal energy plot can be quickly developed for this hull at its design speed. As compared to the flow-friendly Wigley hull (Figure 4), you can see in the figure below a substantial peak toward the stern just upstream of the hull inflection. You will also note the larger wave-making magnitude of the RoPax hull due to its less streamlined sectional area curve (notably due to the sharp forward shoulder, prolonged mid-ship, and the stern inflection – see Figure 7).

This upstream influence of a transition is typical of hydrodynamic bodies. For example, a 2D foil study can confirm that a downstream inflection would cause an upstream pressure increase. Using knowledge of this tendency for designer-guided optimisation, the naval architect can look for peaks that are "out of character" and look downstream (toward the stern) for hull form characteristics that might be modified.

A simple revisit to the original RoPax CAD model allowed the naval architect to revise and smooth the stern inflection. The wave energy plot for the modified stern is shown below. This small re-design – guided by the ADVM method and its corresponding wave-making energy plot in NavCad Premium – delivered a 35% savings in wave-making resistance and a 14% total resistance reduction (Figure 8).

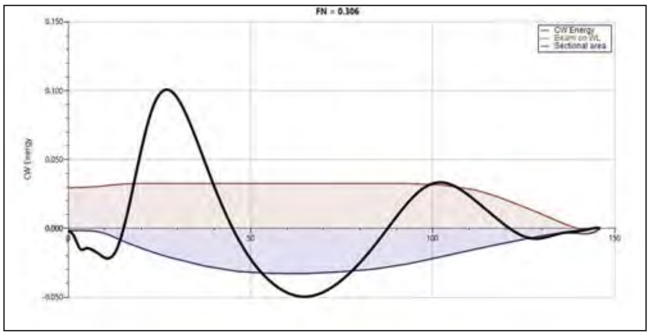


Figure 7 – Original RoPax hull energy plot

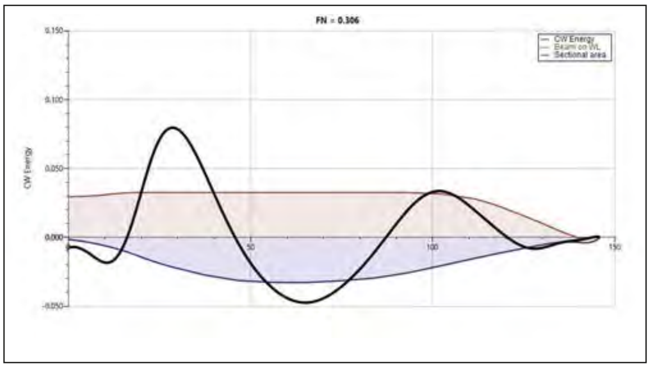


Figure 8 – Modified RoPax hull energy plot

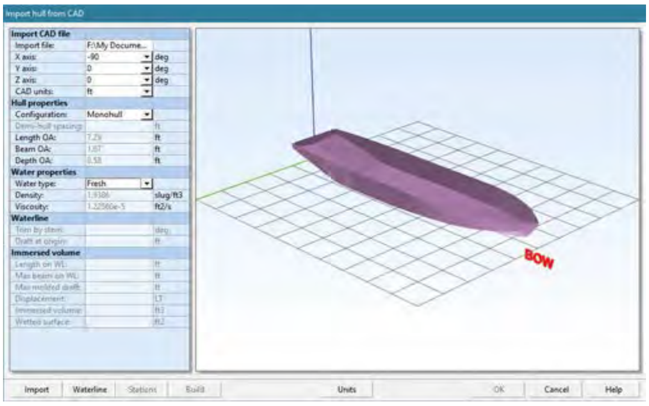


Figure 9 – Hull CAD import for data capture (step 1)

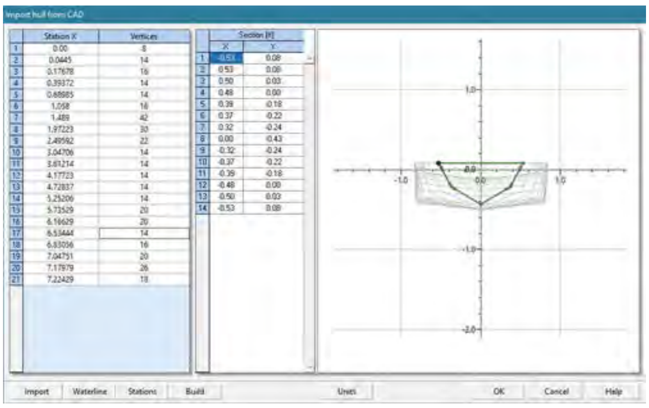


Figure 10 – Extracted offsets (step 2)

## Data requirements and workflow

The hull form data necessary for the parametric "minimum drag" analysis or for the ADVM method (and the wave energy plot) can most easily be captured using a new "hull import from CAD" utility in NavCad. The process starts with a user-generated STL file, which is a comparable data source as used by CFD and higher-order analyses. This creates a

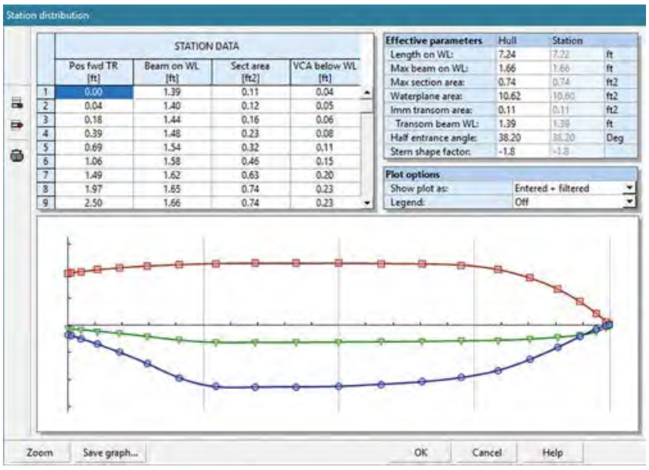


Figure 11 – Captured parametric and longitudinal station distribution data

version of the geometry based on faceted panels. The following screenshots illustrate the import of a CAD file in STL format for a research vessel : import, offsets, and captured data (Figures 9, 10 & 11).

## Conclusions

Through the application of a 'designer-guided' optimisation strategy, naval architects can evaluate proposed hull form geometry both in parametric and distributed volume domains. Only by keeping the naval architect in the design loop can the hull form geometry effectively be optimised for hydrodynamic objectives within the scope of competing disciplines.

Of course, this does not eliminate the potential for additional improvements using higher-order CFD or model testing. In fact the opposite is true. By incorporating designer-guided hydrodynamic hull form optimisation into a naval architect's regular design process, the design will be system-ready, pre-qualified, and benchmarked. This makes additional follow-on analyses more effective by devoting resources where they are most useful – by calculating just what is needed, instead of using resources for a hull geometry that may prove to be restricted by the other disciplines of naval architectural design. *NA*

# Small scale maritime distribution and utilisation of LNG

Drawing on two decades of experience in the design and evaluation of numerous newbuild offshore FLNG and FSRU vessels, as well as the design of both conventional and innovative LNGCs and other gas carriers, Keith Hutchinson and David Dobson of Tyneside-based Safinah consider the history and development of small scale floating LNG

There is continued growth in the application of natural gas for both industrial and domestic consumption and electrical power generation. This has led to an increase in its global and local transhipment in its cooled transitory form of Liquefied Natural Gas (LNG), primarily by sea. This is generating a significant and rising demand for small LNG Carriers (LNGCs), bunker vessels etc., together with small scale storage, processing and offloading vessels and power generating barges etc.

Small scale floating LNG assets can inherently provide a supply of natural gas to locations where larger floating assets or traditional (fixed) land-based infrastructures are either uneconomic, prohibited by geographical, geological or political issues, or where demand is only temporary or seasonal. Additionally, the speed with which small scale LNG assets can be brought into commercial operation favours applications where there is a short mobilisation/execution schedule. Locations particularly suitable for small scale floating LNG include the small emerging markets of island and coastal states, communities/facilities not connected to an existing 'national grid' of gas pipelines and isolated industrial or power generating plants; for instance, gas-fuelled power stations or high energy industrial consumers. Small scale LNG is a particularly cost-effective vehicle for providing natural gas to market and facilitates solutions that are low risk, flexible and inherently able to readily adapt to changing market conditions.

The small scale floating LNG supply and utilisation chain consists of many ship and vessel types such as LNGCs, LNG Bunker Vessels (LNGBVs) or LNG Bunker Barges (LNGBB), LNG Floating Storage and Offloading (LNGFSOs) reception/distribution vessels, Floating, Storage and Regasification Units (FSRUs), LNG Floating Power Barges (LNGFPBs) or ships, etc. As with most floating artefacts, each has many common and some unique, but often conflicting and diverse, design and operational criteria which must be addressed coherently within the design process in order to generate robust and safe solutions. Hence, the selection of appropriate technologies and design configurations is of paramount importance.

Replica of the *Methane Pioneer*. Image courtesy of The Science Museum

## First LNGCs

The oceangoing transhipment of LNG can be traced back six decades to the late 1950s, when a former Second World War built cargo ship MS *Marline Hitch* was converted to transport LNG in bulk from the United States of America across the Atlantic Ocean to the United Kingdom. The 4,639 Gross Registered Tonnage (GRT) *Methane Pioneer*, as it was renamed, had a cargo capacity of 5,088m$^3$ of LNG. It transported the world's first ocean cargo of LNG in early 1959, leaving Lake Calcasieu in Louisiana on 25 January and reaching Canvey Island on the River Thames 27 days later.

The two first purpose-built LNGCs were commissioned in the early 1960s for the shipping of LNG from Algeria for British Gas. The ships in question were the 1964 built SS *Methane Princess* and SS *Methane Progress* and had a capacity of 27,400m$^3$ of LNG.

## LNG production

As discussed above, in 1964 the United Kingdom and France made the first large

*Methane Progress*, built in 1964

scale commercial LNG trade, buying gas from Algeria. Moving on four decades, in 2006 Qatar became the world's biggest exporter of LNG and as of 2016 only 18 countries export LNG with Qatar being the source of 30% of the world's LNG exports.

Originally, due to the large capital investment in land-based liquefaction and storage terminals, the specialised LNGC tonnage and land-based reception storage and regasification facilities, the LNG trade was exclusively carried by 'liner services' with ships on long-term charters. However, over the past decade or so a spot trade market has emerged which can be a very lucrative sector.

At present the natural gas market is about 60% of the crude oil market (measured on a heat equivalent basis), of which LNG forms a small but rapidly growing segment. Much of this growth has been driven by the need for clean fuel (discussed below) and some substitution effect due to the high price of oil, primarily in the heating and electricity generation sectors. To illustrate this growth, in 1970 global LNG trade was 3 million tonnes per annum (MTPA); over four and a half decades later in 2016 it had increased nearly one-hundred-fold to 258 MTPA. The global trade in LNG, increased at an average rate of 7.4% per year over the decade from 1995 to 2005, and is expected to continue to grow substantially in the future with an increase at 6.7% per year to 2020 predicted.

## Small LNGCs

Currently there are very few small LNGCs in comparison to the 'conventional' (approximately 125,000m$^3$ to 180,000m$^3$) and large (approximately 210,000m$^3$ to 266,000m$^3$), LNGC fleet which numbers over 500 in service and in excess of 100 under construction. The fleet of small LNGCs can be summarised as follows:

- less than 10,000 metres$^3$ capacity – 13 ships;
- 10,000m$^3$ to 20,000m$^3$ range – 14 ships;
- 20,000m$^3$ to 30,000m$^3$ range – 12 ships;
- 30,000m$^3$ to 70,000m$^3$ range – 4 ships;
- 70,000m$^3$ to 80,000m$^3$ range – 9 ships.

Given the projected growth in utilisation of LNG, the fleet of small ocean-going and coastal LNGCs and coastal and inland barges is likely to grow significantly in the near future.

## LNG distribution

As the transportation infrastructure grows, inland distribution will be required from the deepwater ports where FSRU facilities exist to inland waterways for use by canal, road and rail. Regulations in inland waterways are driving the use of clean fuels in order to provide cleaner air in residential and rural areas. Transhipment of LNG in smaller parcel sizes will be a necessity. Whilst marine solutions exist for large ports, specialist ships will be required for inland distribution. These could take a variety of forms: containerised shallow draught; low air draught ships; barge/tug combinations; etc.

Some pioneering schemes are already underway. In the Netherlands, a National LNG infrastructure has been established with seven LNG fuel stations operating, 100 LNG-fuelled trucks on the road, two inland vessels and a small scale LNG tanker in service and a LNG bunkering station for ships in Rotterdam. Meanwhile, there is integrated plan for the Rhine-Main-Danube waterway network which will require many transportation vessels to be converted to LNG. Canadian Great Lakes operators are also examining LNG as an emissions free transportation network.

## LNG Bunkering

There were six LNG bunkering ships and barges in operation at the beginning of 2018. Initially these specialist vessels are being introduced to service medium to long-term charter parties that will be supplemented by ad-hoc opportunities. One vessel is designed specifically to service only one dedicated ferry service. Vessels of between 200m$^3$ and 7,500m$^3$ are either in operation or planned. However, schemes that utilise vessels with as much as 20,000m$^3$ are under consideration to support future marine LNG consumers such as very large container ships.

The development of LNG bunkering at large ports requires a dedicated service within a major port or adjacent ports in close proximity. Services are being driven by the needs of a major LNG users and producers. New bunkering hubs are also developing which will leverage existing bulk LNG infrastructure, and the majority of the world's top ten bunkering ports are now either offering LNG bunkering or have firm plans to do so by 2020. Currently LNG bunkers can be obtained at 11 European ports with a further 14 ports having immediate plans to develop a service.

As the number of LNG consumers increases the number of LNG bunker vessels required will need to increase to meet the growing demand. It is likely that a range of vessel types will be developed to suit individual port and regional requirements. Smaller ports may well utilise a multi-fuel capable vessel that can carry say LNG, Liquefied Petroleum Gas (LPG) and conventional Marine Diesel Oil (MDO) / Heavy Fuel Oil (HFO) in order to remain competitive and service diverse demands.

## Fuel regulatory drivers

IMO MARPOL Annex VI Regulation 14 is designed to limit emissions of the harmful pollutants sulphur oxides (SOX) and particulate matter (PM) from ships. These regulations impose strict limits on sulphur content in marine bunker fuel oils and have been progressively introduced since 2006 with particular limits for coastal areas known as Emission Control Areas (ECAs).

Outside an ECA, the sulphur content of any fuel used on board ships should not exceed 3.50% m/m, dropping to 0.50% m/m with effect 1 January 2020. Inside an ECA, the sulphur limit is 0.10% m/m since 1 January 2015.

The regulation defines two categories that can control emissions: primary, in which the formation of the pollutant is avoided, or secondary, in which the pollutant is formed but subsequently removed to some degree prior to discharge. Primary refers to the adoption of cleaner fuels such as Low Sulphur Fuel Oil (LSFO), LNG etc. Secondary alludes to the fitting of equipment to remove the exhaust gas pollutants, i.e. scrubbers.

In Europe there are ECAs for the Baltic Sea and North Sea (although for SOx only). The North American and United States Caribbean Sea areas cover SOx, NOx and PM. The parameters of these zones aree defined in Appendix VII of Annex VI of MARPOL. Future ECA's may include the Mediterranean Sea, Japanese coastline, Mexican coastline, Malaysian Straits / Singapore, and the Norwegian coastline.

## Marine bunker fuels

HFO with high-sulphur content accounted for 76% of marine bunker fuel demand in 2010, but LSFO is generally seen as an expedient option for compliance with SOx emission regulations. Abatement technologies, such as scrubbers are typically perceived as aquick fix. But for the long-term, LNG-fuelled engines are commonly felt to be the most viable option, particularly for ships engaged on liner trades.

LNG bunkering is expected for short sea shipping within ECAs and it may eventually cascade into the deep-sea trades facilitated by international regulations. But it should be kept in mind that LNG bunker demand is highly dependent on the LNG price differential with other fuels, such as HFO and MDO.

## Gas fuelled ships

It is interesting to note that the first gas powered ship can be traced back to the 1911, when the small 279 GRT tanker *Holzapfel 1* was built by the J.T. Eltringham Shipyard in South Shields on the River Tyne. The ship was fitted with revolutionary gas burning engines, which prior to this ship had not existed on either land or sea. The gas generators were developed by two German brothers, Albert and Max Holzapfel, and built in Stockton-on-Tees.

There is no doubt that increasing regulatory restrictions and the availability of cleaner cheaper fuels will result in more ships utilising LNG as an alternative to bunker or distillate oil as it is cleaner burning and hence more environmentally sustainable. There are currently approximately 800 ships planned, in build or in operation that utilise LNG as a fuel. Of these, only 120 are true trading ships i.e. not LNGCs. However, this is expected to grow significantly in the near future and contracts have been placed almost every conceivable ship type.

## Small near-shore storage

A small LNG Floating Storage and Offloading (LNGFSO) vessel is a flexible, cost-effective way to store LNG where no onshore infrastructure exists or requirements are small or temporary in nature, They are cheaper and quicker to establish than bespoke onshore storage facilities. Small LNGFSOs can be moored in many different ways, either at sheltered inshore locations or unsheltered near-shore locations, utilising mooring designs suitable to the water depth.

The trailblazing *Holzapfel 1*, from 1911

As with conventionally sized versions, LNGFSOs receive LNG from LNGCs and store it for later distribution for bunkering of LNG-fuelled ships, small LNGCs for coastal or inland waterways transportation, or land-based road or rail tankers.

## Near-shore regasification

Due to the required proximity to land, FSRUs (Floating, Storage and Regasification Units) are generally moored in a sheltered near or inshore location via a turret, buoy or directly at a fixed jetty, pier or quay. Like LNGFSOs, both small and conventional FSRUs receive LNG from LNGCs, store but then also regasify it, at a required and sometimes variable rate, back into its stable gaseous form (predominantly methane). This process utilises mature but previously exclusively land-based technologies, such as sea water or saturated steam heating etc., for export to a jetty or shore via a subsea pipeline. Typically, this gas is to service process, power or domestic consumers.

A small FSRU is a flexible, cost-effective way to receive and process shipments of LNG where no onshore infrastructure exists or gas requirements are small or temporary in nature. They are are cheaper and quicker to build than onshore plants, hence are an ideal technology for low commodity projects. Some vessels have been designed for long-term charters at a fixed location and others have retained the flexibility to operate as LNGCs hence allowing them to undertake shorter FSRU charters and rapidly returning to trading as LNGCs or redeployed globally.

## Near-shore power generation

Traditionally, the use of Gas Turbines (GTs) coupled to electrical generators has been common practice in offshore installations as they can burn directly a percentage of the field gas to satisfy a fixed platform or FPSO's power requirements. The use of a combined GT and waste heat Steam Turbines (STs) – namely, combined cycle power generation – is standard practice in land-based gas fired power stations but not offshore as the installations are on the whole not of a size to raise steam of sufficient quality and quantity. However, medium speed (and now slow speed for ship propulsion applications) dual and tri-fuelled diesel engines are readily available and used both in land-based, marine and offshore applications as prime movers for direct-

A diesel fuelled Floating Power Barge

drive or electrical power generation.

## Powerships and boats

A Powership is typically a self-propelled sea-going ship converted from merchant tonnage. Powerships are simply floating power plants for deployment to locations where there is either temporary or urgent electricity needs for an existing grid due to unforeseen circumstances. Examples typically utilise multiple diesel driven generators, either liquid fuel only i.e. HFO, MDO etc., or possibly dual-fuel utilising natural gas if available at the moored location. Powerships can obviously also utilise single or multiple GTs, gas engines, boilers and STs etc..

A Power Barge is a very similar concept to a Powership, but it is not self-propelled. Currently there are nearly one hundred power barges deployed and a typically asset will generate more than 100 MWe of electrical power. Power Barges have been deployed all around the world and a typical deployment is three to five years. A logical combination of the Power Barge is with the technology of the small scale FSRU concept i.e. a modestly sized, re-deployable, LNG fuelled Floating Power Barge (LNGFPB). As discussed above, most existing Power Barges generally use either MDO or HFO to fuel the generating sets, whilst a LNGFPB fuelled by LNG represents an environmentally attractive and acceptable, and possibly more economical option.

A further adaptation of a fixed LNGFPB is the concept of a small Propelled Power Barge (LNGPPB) to provide 'shore supply' to ships which are docked in harbours where there is not sufficient electrical power at the quay and it is undesirable to run the on-board diesel generators. The LNGPPB is one of several options that have been developed to provide 'clean shore-supply' to ships of all sizes, including the largest cruise liners, when docked in harbour.

## Conclusions

As with all investment decisions, a thorough understanding of the market and economic factors pertinent to the application of a small-scale LNG is key to its correct and optimal sizing, solution selection and specification. As previously identified the small-scale LNG is eminently suited to providing a clean and environmentally attractive fuel for a range of marine and land-based applications, from local hubs to onward land-based distribution via road trucks or rail tankers, seaborne coastal transportation and for bunkering of LNG fuelled ships. *NA*

## Disclaimer

The views expressed in this article are those of the authors and do not necessarily represent those of the organisations with which they are affiliated and the professional institutions of which they are members.

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The movement of liquefied gas by sea has been well established. LNG accounts for a significant part of the growth in the global energy supply and despite the recent economic situation the future demand for LNG/LPG carriers, floating storage, and processing systems is expected to increase.

While some companies are building larger, or faster, vessels to take advantage of economies of scale, others are looking at developing small vessels for shortsea and coastal trades to help create LNG distribution networks.

There is also a growing interest in floating production, storage and offloading systems for offshore field development and re-gasification systems and plants designed to avoid the need to construct land based processing and distribution centres.

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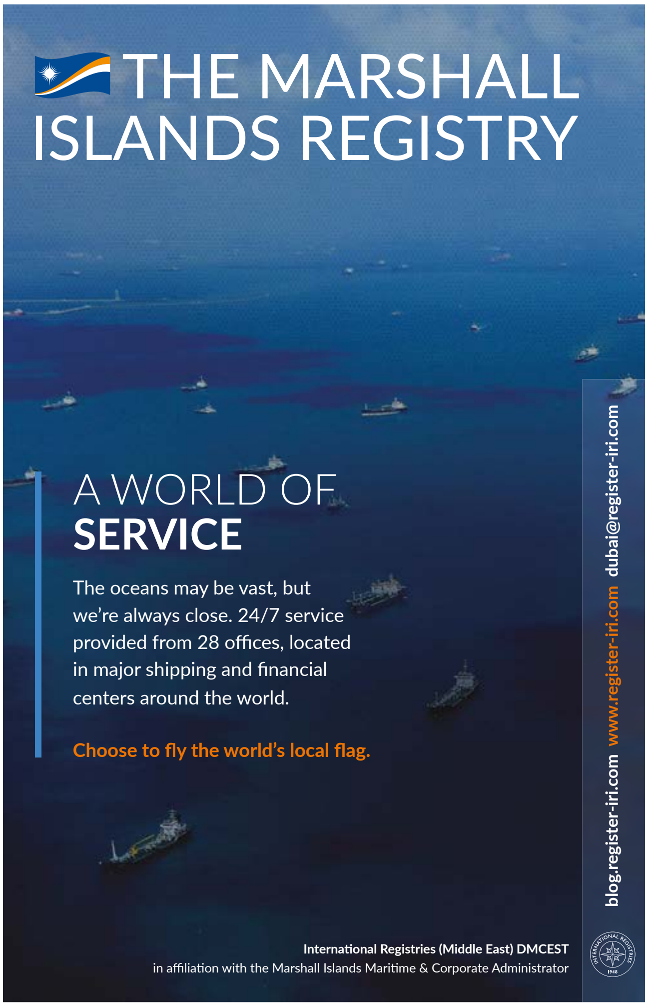


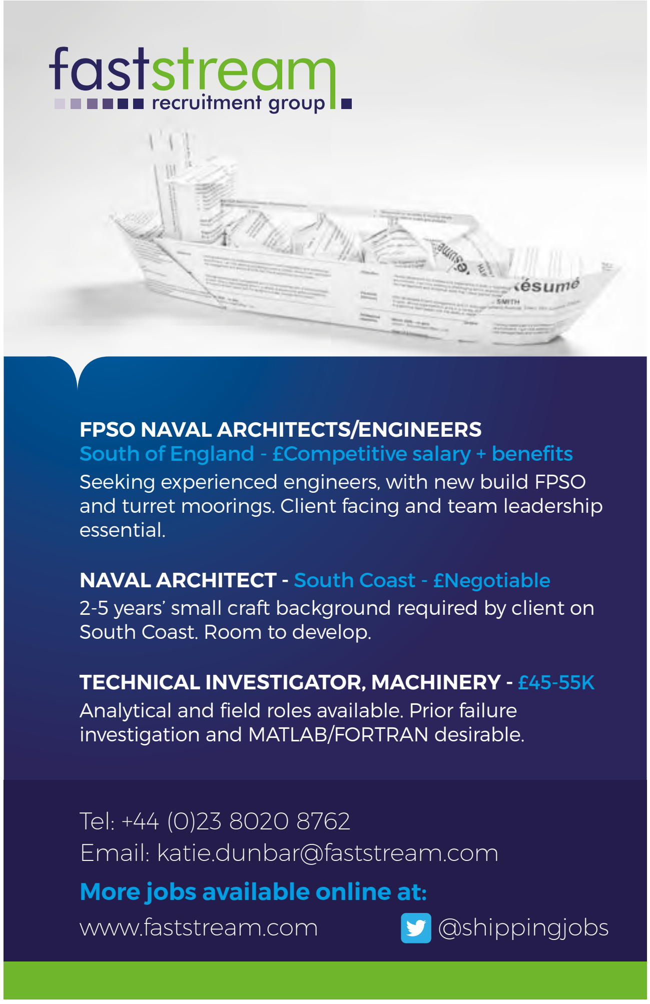


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**By Fred Walker FRINA**
Ships and Shipbuilders describes the lives and work of more than 120 great engineers, scientists, shipwrights and naval architects who shaped ship design and shipbuilding world wide. Told chronologically, such well-known names 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.
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**Shipbuilders** seek to ensure they can improve the design of ships to satisfy progressively more stringent requirements of the ship-owners, together with increased productivity and cost efficiency.



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**Relevant Topics:**

ICCAS encourages papers on all applications of computing and information technologies for use within the Shipbuilding, Marine, and Ship Operation related industries.

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- Evaluation, selection and implementation of a new system.
- Enhancement and/or improved use of existing computing and IT systems.
- Efficient use of data and information captured in Computing Systems.
- Research and development of a future applications of Computing Technologies the industry.
- Vendor development of system capabilities and/or functionality.
- A vision of the future potential use of Computing Technologies within the industry.
- Using Computing Technologies in a collaborative or multi-site environment.
- Procedures and practices implemented to maximise use and benefits of Computing Technologies.
- Improvements in productivity and/or performance due to the use of Computing Technologies.
- Success in applying advanced technologies (such as simulation, AR/VR, Engineering Analysis, Digital Manufacturing, Big Data, Digital Twin, Knowledge Systems, etc).
- Improvements in manufacturing quality/accuracy/productivity due to computing methodologies.
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ICCAS attracts topics from any stage of a ship lifecycle, from concept and early design, through detail design, planning and project management, manufacturing, production and assembly, build, and in-service operation.

Topics such as a supplier using computing technology to enhance equipment performance, a classification society that uses computing technologies to improve the quality and format of data for approval assessment, or a ship operator using computing technologies to optimise performance, are very welcome.

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