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Editor: Richard Halfhide
Editorial Assistant: Kaylee Maddison
Production Manager: Nicola Stuart
Advertisement Production Manager: Stephen Bell
Subscriptions & Publications Manager: Tasharna Francis
Publisher: Karl A Monk

Advertising Sales: J P Media Services
Email advertising: jpayten@jpmediaservices.com

Telephone: +44 (0)1737 852135

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Editorial Office:
8-9 Northumberland Street
London, WC2N 5DA, UK
Telephone: +44 (0) 20 7235 4622
Telefax: +44 (0) 20 7245 6959
E-mail editorial: editorial@rina.org.uk
E-mail production: production@rina.org.uk
E-mail subscriptions: subscriptions@rina.org.uk

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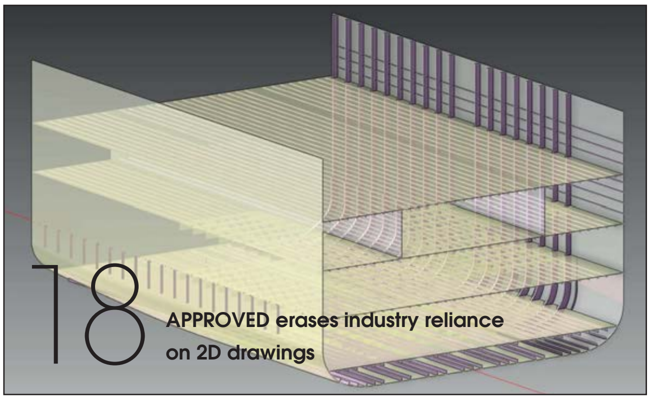

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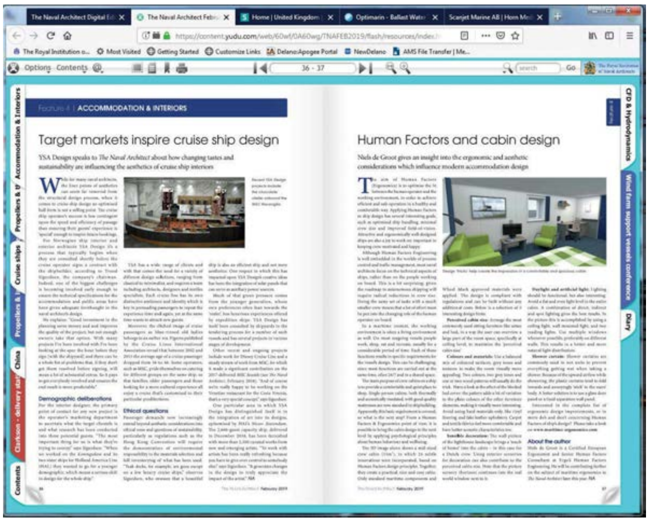

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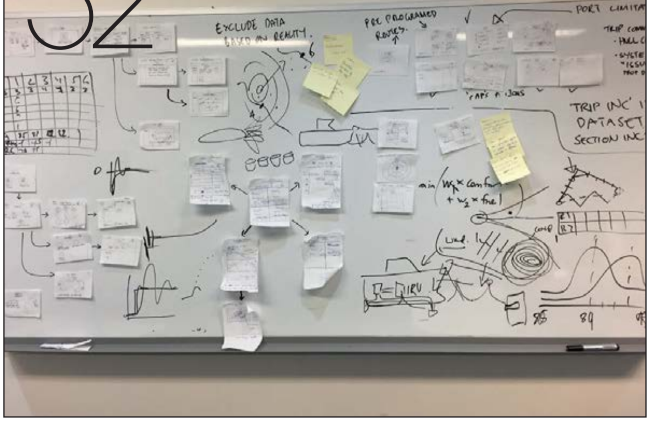

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Slow down, it's not that simple

Grassroots movements such as Extinction Rebellion are piling pressure on governments

On the 30 April, shortly before this edition of *The Naval Architect* went to press, a group of 110 shipowners published an open letter to IMO member states in support of a French initiative for mandatory speed measures that would cut shipping's carbon intensity by at least 40% by 2030.

Citing the example of the dramatic reduction in the global fleet's GHG emissions following the 2008 financial crash, when slow steaming was widely implemented as a cost cutting measure, the strategy would cover both existing ships and newbuildings. The signatories state in the letter that their preference would be for the setting of maximum average speeds for container ships, with maximum absolute speeds for all other ship types. In order to achieve this 40% target, reductions will need to start being realised by 2023. The letter concludes by calling upon IMO delegates to support the proposal at MEPC 74 on 13-17 May.

But there are those who believe such a step would in reality be counterproductive and slow the low-carbon transition. In a statement issued in April, Anna Ziou, policy director at the UK Chamber of Shipping, described the proposal as "problematic" in its implementation and enforcement, given that it hinged on speed simulation studies that assumed ships would always operate at a certain speed.

"Looking at these assumptions from a more realistic setting, the savings could be minimal or even negative. The actual fuel consumption benefits of low speed depend on many factors such as the type and size of the ship, the area of operation, weather conditions, etc," said Ziou.

It's hard not to be cynical and wonder whether there's some sleight of hand at work. In March, the Institute of Shipping Economics and Logistics (ISL), with the publication of its *Shipping Statistics and Market Review 2019*, noted that while world merchant fleet growth in 2018 was just 2.6%, the smallest in 15 years, it has had little bearing upon the low freight rates and ship prices. Of the 287 yards the ISL says are currently engaged in commercial shipbuilding, only around half have received new orders, such is the overcapacity in all the main fleet sectors.

Slow steaming could raise transportation costs, particularly on deep-sea voyages, while buying shipowners more time for the development of technologies capable of achieving the longer-term emission targets. But it also creates the potential for a chicken and egg scenario where less greener technologies are implemented in the short term because of the low take-up. The debacle that surrounded the Ballast Water Management Convention and the current uncertainty concerning the acceptability of open-loop scrubbers apropos the sulphur cap have done little to instil confidence among shipowners, equipment providers and regulators alike.

The other day I received a telephone call from a fellow journalist asking me whether I thought it was possible to differentiate between efficiencies implemented for cost savings and those for the good of the environment. My response (or at least the one I'm giving now) is that it's a bit like the psychologist Edgar Rubin's famous optical illusion in which either two faces or a vase can be perceived, but not at the same time. Rhetoric can be flexible according to the needs of any given arguments. That's probably not a very satisfying answer to a readership used to dealing with empirical values. That said, it's no more useful to regard the typical shipowner as a grasping neoliberal with no regard for the planet their children will inherit than as an idealist who will drive their business into insolvency to try and save it.

But with the growing influence of popular pressure groups such as Extinction Rebellion, which caused disruption over Easter with its sit-down protests in central London, shipping must be wary of the snowballing body of climate change evidence. Given that governments by their very nature must reflect public sentiment, its efforts at self-policing may be deemed inadequate much sooner than was anticipated when IMO's GHG strategy was agreed little more than a year ago at MEPC 72. IMO secretary general Kitack Lim acknowledged as much recently, commenting that the shipping industry's carbon cutting ambitions don't go nearly far enough.

That's highly unlikely to translate into a revised global target of zero GHG emissions from shipping by 2050 though, even if there is plenty of discussion about the feasibility of zero emissions beginning to emanate. There's also the not insignificant issue of whether it's even feasible without the requisite technological maturity. However, conservative goals justified in the (self) interests of pragmatism should and increasingly will be challenged over the coming months and years as the global warming counter offensive coalesces into meaningful actions. *NA*

Zero-emissions

NCE Maritime CleanTech thinks up zero-emissions cruising solutions

NCE Maritime CleanTech, a Norwegian shipping and technology cluster organisation, has developed what it believes is a future-proof concept for sustainable zero-emission cruising.

Launched at the Seatrade Cruise Global exhibition in Miami in April, the concept showcases an evolutionary series of cruise ships designed to meet the 2026 regulation for zero-emissions in the Norwegian world heritage fjords.

Cruise tourism in Norway has rapidly grown in recent years, with some suggesting that by 2040 one million cruise passengers will sail along the country's coast.

Created in cooperation with leading cruise lines including Eker Design, Carnival Corporation and Royal Caribbean Cruises, the concept proves it is possible to meet Norway's zero-emission goal, said Ronald Strøm, a project participant and technical manager at Edda Accommodation.

The initial stage of the design concept involves loading containerised power packs onto the open decks of retired PSV tugs, essentially converting them into external floating batteries. The PSVs would then tug the cruise ship through the regulated areas of the fjords while supplying power to its hotel through cable links, allowing the ship to operate without running its engines.

By 2030, at which point all fjords are to be emission free, NCE Maritime CleanTech has envisioned a new pyramid shaped purpose-built cruise ship. The futuristic vessel would use either batteries or fuel cells, complemented by wind and solar energy.

Eventually, alternative methods of waste handling, heating and cooling would also be incorporated into a modular constructed vessel.

"We also believe that there must be a shift towards more energy-efficient and region-specific vessels in the future. The concepts that have been developed will act as a platform for further innovation and form the basis for a number of new innovation projects," said Hege Økland, CEO of NCE Maritime CleanTech.

Founded in March 2011, NCE Maritime CleanTech is part of a government supported cluster programme for clean maritime solutions. Its aim is to establish sustainable projects with commercial potential (see also p.26).

The concept zero-emissions cruise ship developed by NCE Maritime CleanTech

Regulations

IMO's data exchange rule comes into force

The IMO's new global rule stating that ships and ports must exchange facilitation (FAL) information electronically took effect 8 April.

With more than 10 billion tonnes of goods shipped across the world each year, the goal of the regulation is to reduce administrative burden and move towards the standardisation of electronic messages.

It aims to make cross-border trade hassle free and logistics chains more efficient by using the maritime single window.

Defined under IMO's Convention on Facilitation of International Maritime Traffic (FAL Convention), the 'single window' enables all the information required by public authorities to be submitted via a single point of contact, without duplication. Data that must be exchanged electronically includes the arrival, stay and departure of ships, persons and cargo.

A maritime single window has been implemented in Antigua and Barbuda. The project, which was developed with Norway's support, may benefit other Caribbean countries and regions across the globe.

The step has been marked as a "significant move" in shifting the maritime industry and ports towards a digital world.

Adopted in 1965, the FAL Convention seeks to achieve the smoothest transit in ports of ships, cargo and passengers as possible. It lists the information public authorities can demand from a ship and outlines the practices for simplifying formalities, procedures and documentary requirements, for forms such as cargo declaration, crew's effects and dangerous goods.

Under the new requirement, all national authorities should now have provision for electronic exchange of this information.

LNG carriers

Qatar launches largest LNG shipbuilding program

Qatar Petroleum has announced an invitation to tender for the construction of a new LNG fleet that could exceed

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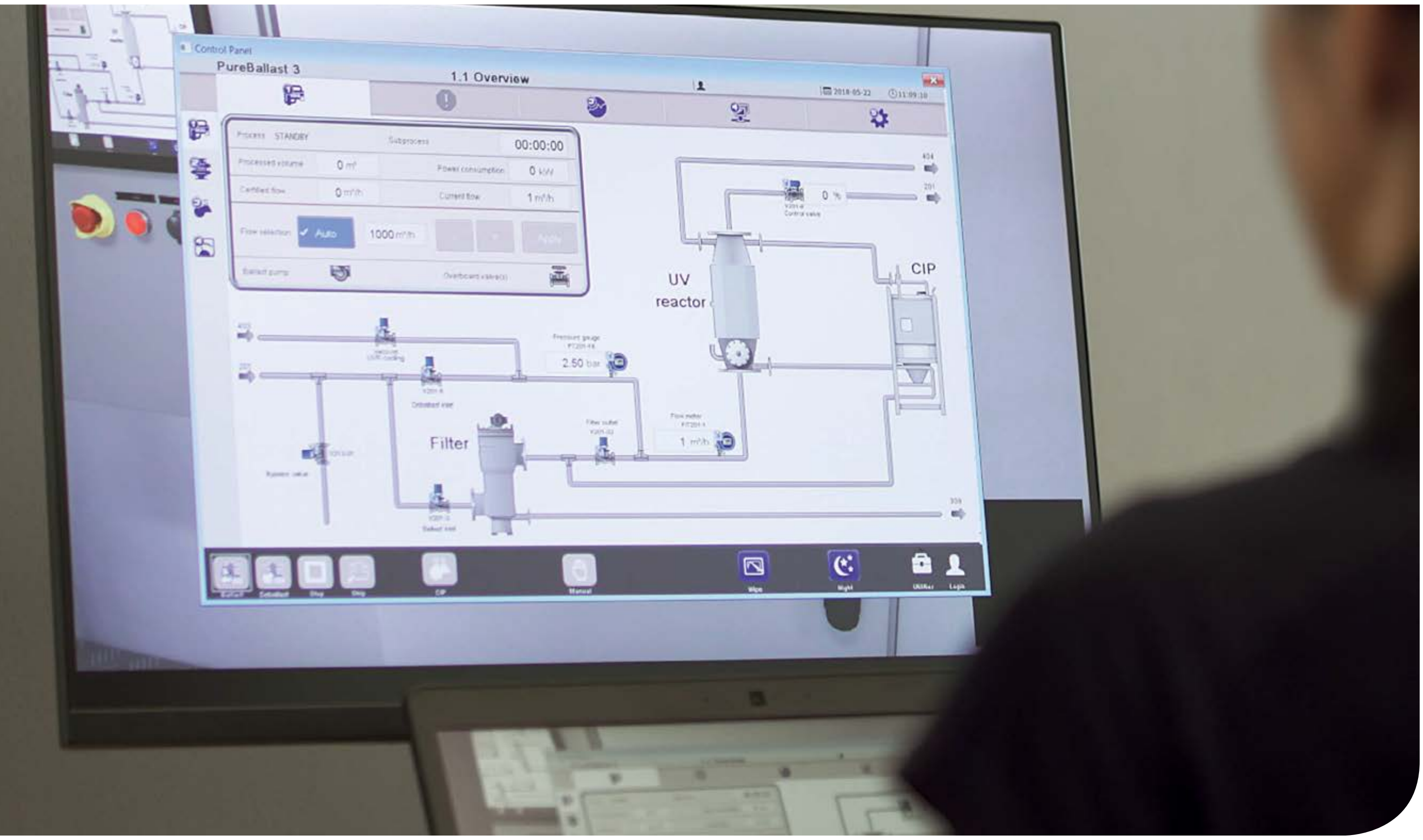

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100 newbuild carriers over the next decade.

The oil and gas giant's initial plans call for the construction of 60 LNG carriers, with the potential for at least an additional 40 vessels.

The shipbuilding program will support the shipping needs of Qatar's North Field Expansion project, which is expected to increase the country's LNG production capacity from 77 million tonnes per year to 100 million tonnes by 2024.

Qatar ranks as the world's second largest exporter of LNG. The North Field, located of the north-east shore of the Qatar peninsula, covers an area of more than 6,000km^2. Gas produced from this field is processed into LNG, NGL and GTL.

The proposed tender also covers shipping requirements from the Golden Pass LNG export project in the US, which is planned to start by 2024. All LNG from the project will be purchased and shipped by Ocean LNG, a joint venture between Qatar Petroleum and ExxonMobil.

In addition to expanding the carrier fleet, the tender offers the opportunity for replacement requirements on Qatar's existing LNG fleet.

Qatargas, operator of the world's largest fleet of LNG carriers, will oversee the shipbuilding program on behalf of Qatar Petroleum.

Scrubbers

Höegh Autoliners says no to scrubbers

Norwegian transport company Höegh Autoliners has decided against installing scrubbers on any of its pure car and truck carrier vessels.

To comply with the IMO's 2020 regulations, the company will opt for Low Sulphur Fuel Oil (VLSFO) instead.

In a statement, Höegh Autoliners announced it had settled on the decision after considering fuel usage, the design of its vessels and open loop scrubber bans in some port areas. However, the company's CEO questioned the technology's environmental sustainability as well.

"First of all, the reasoning behind the IMO 2020 regulation is to reduce emissions from the global trading fleet. I am not so sure scrubbers will support that mission", said Ivar Myklebust, CEO of Höegh Autoliners.

"Surely, scrubbers will reduce emissions to air, but it appears as it will just move the emissions to the sea instead."

He also argued that scrubbers could increase the carbon footprint of a vessel as it adds weight and requires tens of thousands of tons of water to wash through the systems each day. To do this requires energy, which comes from the burning of more high sulphur fuel.

Ports that have banned open loop scrubbers due to their impact on local waters include Singapore, Shanghai and Fujairah. Given that Höegh Autoliners' vessels spend 60-70 days per year in port, often in areas where scrubbers are banned, Myklebust said the investment would make little sense.

"Why focus on using a product that will be banned?" Myklebust said, referring to the High Sulphur Fuel that those who install scrubbers will continue using. "I want to hear from the refineries how they will secure us with sufficient supply of a product that is legal, namely the Very Low Sulphur Fuel Oil and Low Sulphur Marine Gas Oil."

Additionally, the structural design of the company's Pure Car and Truck Carriers is not ideal for scrubbers. At 14 decks high, the installation process would be difficult, as a scrubber would have to go from the engine room up through the entire vessel to the chimney.

Autonomous ships

Singapore announces innovation lab for smart ships

The Maritime and Port Authority of Singapore (MPA) is set to embrace an autonomous future with the launch of its new Maritime Innovation Lab (MIL).

The facility, which is part of the MPA's Living Lab, was introduced on 9 April at Singapore Maritime Week 2019.

MIL projects will focus on building local technological capabilities and developing the "next-generation of port operations", including the experimentation of autonomous ships.

Located at PSA Vista in Pasir Panjang, the developer space will help ensure Singapore, which ranks as one of the busiest ports in the world, is future-ready.

Through the innovation lab, MPA hopes to accelerate the development of new operation concepts while advancing opportunities within automation, data analytics and intelligent systems.

"The setup of the Maritime Innovation Lab is an important milestone in Singapore's journey to be the global maritime hub for connectivity, innovation and talent," said Dr Lam Pin Min, the senior minister of state for transport.

In order to prepare for a digitised future, the port authority has established a dedicated cross-agency steering committee which will develop a roadmap for its autonomous maritime operations and capabilities.

The space will feature a S$9.9 million (US$7.32m) Next Generation Vessel Traffic Management System Lab that is set to advance information exchange between ships and port authorities. It is scheduled for completion by 2021.

To support its goals, MIL has partnered with serval industry firms, including ST Engineering, Keppel, Mitsui and Lloyd's Register, to conduct five different autonomous ship projects worth a total of S$7.2 million

(US$5.3m). These projects aim to enhance navigational safety, port infrastructure and regulations of autonomous operations.

Companies, research institutions and local universities will also be able to take advantage of the space to develop and test their own maritime solutions.

MPA and partners introducing the Maritime Innovation Lab at Singapore Maritime Week

Classification

ClassNK releases guide for sulphur cap

Japan's classification society, ClassNK, has published a guidance plan to support the maritime industry prepare for the IMO's 2020 sulphur cap.

The 'Guidance for onboard use of Compliant Fuel Oil with Sox regulation from 2020' recommends that ships develop and keep an onboard implementation plan for switching to compliant fuels. It provides industry members with an example implementation plan and outlines how the ship may prepare in order to comply with the upcoming 0.5% sulphur limit.

The sample plan covers preparation, such as risk assessment and mitigation, as well as details about necessary fuel oil system modifications and tank cleaning when switching fuels.

Additionally, it suggests that companies determine the availability of suitably trained crew, who are familiar with the ship's fuel system and fuel changeover procedure.

With the anticipated uptake of more low sulphur blend fuels, ClassNK has also identified five properties of compliant fuel that shipowners should take into consideration with its use. These properties include: compatibility, low viscosity, cold flow properties, cat-fines, and ignition/combustion quality.

The new guide explains the basic characteristics of each property and any potential safety implications associated with them.

Although a ship implementation plan is not a mandatory requirement, it is encouraged and may be complemented with a record of actions taken by the ship to become compliant with the sulphur cap.

The class society will also provide related appraisal services to confirm that a ship's plans are compliant. *NA*

Taking Norwegian innovation in a new direction?

Norway leads by example at this year's Nor-Shipping, showcasing its technological ingenuity and focus on environmental protection, writes Malcolm Latarche

When the Nor-Shipping exhibition opens on 4 June this year, shipowners, shipping organisations and environmental groups will likely be digesting and commenting on decisions made at MEPC 74, which finishes two weeks prior. At the same time, many of the exhibitors at the event will be showcasing systems, products and services that are intended to meet the requirements of current and future regulations despite sometimes finding that goalposts have been moved.

Scrubber makers in particular must be having mixed feelings about Nor-Shipping for after a surge in scrubber sales through the second half of 2018 and beginning of 2019, potential bans on open loop systems may be having a negative effect on sales. One of those bans will affect the cruise ships calling at Norway's heritage fjords, despite Norway itself allowing scrubbers on any vessel flying the Norwegian flag.

This year, the Nor-Shipping conferences, seminars and workshops are very much environment orientated. The exhibition organisers have partnered with the UN's Global Compact Action Platform for Sustainable Ocean Business, while sustainability and the Blue Economy are central pillars of the conference and special events programme. For 2019, part of the exhibition space will be dedicated to organisations which promote decarbonisation solutions and sustainable technologies.

Nor-Shipping will devote the whole of Hall A to the concept of Blue Economy, showcasing 'tomorrow's business solutions today'. The hall will be transformed into an interactive landscape designed to highlight and accelerate business practices that balance maritime and ocean activity growth with sustainable resource use and environmental protection. Five key focus areas will provide structure for the space: sustainable ocean economy, sustainable infrastructure, decarbonisation, protection of ocean life, and the development and implementation of responsible practices.

These environmental themes are, however, nothing new for Norway. The country was the first to introduce a NOx tax, the funds from which have been used to subsidise several maritime projects and ship adaptations aimed at reducing NOx emissions. In pursuit of lower NOx emissions, Norwegian equipment suppliers and ship operators have enthusiastically embraced developments such as LNG. Although the alternative fuel has been successfully employed in many ferries and offshore vessels, its appeal for Norwegian operators seems to have diminished as of late.

LNG can also help meet the impending 2020 sulphur cap and could be a stepping stone to the IMO's decarbonisation ambitions. However, Norway is already well down the road to other options in some local applications.

For example, in the country's all-important ferry sector, it is batteries and hydrogen that are grabbing attention. *Ampere*, Norway's first battery powered ferry, entered service just before the 2015 Nor-Shipping exhibition and has since been followed by several more including the carbon fibre catamaran, *Vision of the Fjords*. Norway does have a particular advantage when it comes to battery power because the country is mostly self-sufficient in clean hydro-electric power – something that not all countries can emulate.

Thus far most of the ferries that run wholly or partially on battery power have been small ships but Norway has also targeted bigger vessels. Hurtigruten, the country's long-distance coastal ferry operator, has made headlines with its order for two hybrid expedition cruise ships at Kleven Yard – which it now owns. The first of these, *Roald Amundsen*, is due for delivery this year. Hurtigruten has also decided to hybridise many of its existing 1990s-built vessels and to convert their existing diesel engines to run on LNG or biomethane derived from fish waste.

Even more environmentally ambitious is the project by newly established ferry operator Kystruten, which has contracted with local builder Havyard for four large hybrid ferries. The first ship is due to be delivered in 2021 but is likely to be retrofitted with hydrogen powered technology within a year or so of delivery.

Last December, Havyard received more than NOK100 million (US$11.58 million) in funding from Pilot-E, an association formed by the Research Council of Norway, Innovation Norway and Enova. This will enable Havyard, its subsidiaries and research institutions Sintef Ocean and Protech to move ahead with the FreeCO2ast project which, as the name suggests, aims for zero emission operation. The funding is to be used to develop a hydrogen fuel cell and battery hybrid system that will allow the Kystruten vessels to operate completely emission-free for a large proportion of their planned route between Bergen and Kirkenes in Norway. *NA*

Propulsion

ABB to power new Seabourn expedition vessels

ABB has secured a contract to supply power and propulsion systems for Seabourn's two new cruise ships.

The 170m, 23,000gt newbuilds will be fitted with the Swiss-Swedish company's Azipod propulsion units. In addition, ABB will provide main generators, switchboard, convertors bow thruster motors and remote-control monitoring systems.

Built to Polar Code 6 hull specifications, the expedition ships are designed for operation in the Arctic and Antarctic.

The system will free up space onboard the 264-passenger vessels as well, allowing them to carry extra craft, such as kayaks, rubber boats and a pair of submarines.

Currently under construction in Italy at T. Mariotti shipyard, the *Seabourn Ventura* and the still unnamed vessel are expected to be completed in June 2021 and May 2022 respectively.

The vessels will be connected to ABB Ability Collaborative Operations Centre in order to monitor the performance ABB technology and remotely connect operators with ABB experts when needed.

Seabourn, a Seattle-based cruise company, is the latest operator to opt for ABB's propulsion system. The Azipod units have become a popular choice for expedition vessels with more than 20 exploration cruise ships featuring ABB's propulsion system to date, including the Lindblad Expeditions' *National Geographic Endurance*.

Last month, ABB also announced it would deliver two Azipod propulsion systems for China's first domestically built cruise ship (see *The Naval Architect*, April 2019).

Seabourn chooses ABB's Azipod propulsion units for its newest vessels

Fuels

Shell Marine launches VLSFO friendly lubricant

Shell Marine introduced a new two-stroke engine cylinder oil specially for engines running on 0.5% sulphur fuel in preparation for the IMO's 2020 regulations.

The Shell Alexia 40 has been developed to optimise equipment performance and condition in order to equip shipowners for the upcoming sulphur cap.

Tested at Shell's Marine and Power Innovation Centre in Hamburg, Alexia 40 is reported to have undergone extensive tests onboard four ships with the latest engine types, using IMO 2020-compliant fuels to verify performance at sea.

The new product will be on the market as of 1 June 2019 in Singapore. It will eventually be rolled out to Shell's other main supply ports in countries such as US, China, UAE and the Netherlands.

In a statement, Shell Marine said that it expects most of the world's shipping fleet to comply with IMO 2020 by switching to fuels with a sulphur content of 0.5% and below.

The launch of Shell Alexia 40 coincides with the company's unveiling of its broader range of Shell Alexia products. Its other low sulphur compatible lubricants include Shell Alexia 25 for 0.1% ultra low sulphur fuel and LNG, as well as Alexia 100 and 140 for ships continuing to operate on HSHFO with scrubbers.

Engines

Booster system successfully tested with new LPG-powered engine

Engine manufacturer, MAN Energy Solutions have trialled an LPG fuel condition module (FCM) produced by Swedish tech company, Alfa Laval, with its first LPG-fuelled two-stroke high-pressure marine engine.

According to Alfa Laval, the FCM LPG is the first proven solution capable of providing LPG to a high-pressure combustion engine.

It is essential to pump LPG at a higher supply pressure compared with other low flashpoint fuels, including LNG and methanol, to avoid it changing state and to handle a wide composition spectrum. To deliver LPG at the 53 barg pressure required by the engine, the FCM incorporates new pumping technology and high-pressure heat exchange, which are built into low-pressure and high-pressure skids.

The booster's automation and control system also match the LPG flow to fluctuating engine load without

unnecessary heat input from the pumping and flashing of light fractions in the LPG.

"Both sets of test results verify the booster's ramping functions and its ability to match the output pressure to our engine's changing load," said René Sejer Laursen, promotion manager at MAN Energy Solutions. "In fact, almost no influence from the engine load can be seen, which demonstrates the effectiveness of Alfa Laval's automation and control."

Additionally, the system is capable of full liquid LPG recovery and partial LPG gas recovery when the engine or fuel valve train is purged. This is both economical for vessel operators, as it can prevent fuel lose, and environmentally efficient due to the minimal release of hydrocarbons into the atmosphere.

With MAN currently developing an ammonia-fuelled engine, the FCM LPG was also evaluated for the use with ammonia fuel. For a small investment, the system could be made compatible with ammonia, said Laursen.

Data management

NAPA adopts Inmarsat's IoT service

The Finland-based maritime software company, NAPA, has become the first certified application provider for Inmarsat's new IoT service, Fleet Data.

Developed by Inmarsat and Danelec Marine, Fleet Data collects data from onboard sensors, pre-processes that data and uploads it to a central cloud-based database equipped with a dashboard and Application Process Interface (API).

NAPA then uses the aggregated data to offer services for vessel performance monitoring, analytics and optimisation.

The partnership will allow shipowners and managers to take greater control their data, with the ability to gather information onboard their vessels, transfer it to shore and examine fuel optimisation in real-time.

On average, ship operators plan to spend US$2.5 million on IoT-based solutions within three years and expect an IoT-driven cost saving of 14% over the next five years, according to research published last year by Inmarsat.

Yet, the research also suggested that there would be an even greater uptake in IoT-based solutions if more data could be aggregated and analysed in real-time.

Fleet Data, which was made commercially available earlier this year, is accessible across Fleet Xpress and FleetBroadband and scalable fleet-wide.

"Our NAPA Fleet Intelligence platform is built to utilise ship performance data from all kinds of data sources, such as noon reports, or AIS, and to scale according to the data available, allowing as many vessels as possible to use data to improve their operations," said Pekka Pakkanen, the director of development at NAPA Shipping Solutions.

In addition to Fleet Data, Inmarsat will provide dedicated bandwidth services for application providers across its L- and Ka-band networks.

Radar technology

Wärtsilä launches high resolution radar system

Wärtsilä has unveiled the world's first commercially available K-band maritime radar, which can detect far smaller objects than conventional SOLAS-mandated S or X-band radars.

The RS24 high resolution radar, developed by the company's Guidance Marine unit, helps eliminate protentional blind spots by increasing the visibility of small ships, navigation buoys and other potential hazards close to large vessels.

It is expected to be particularly beneficial for ships that make frequent port calls, including ferries and cruise ships, and improve safety in congested shipping lanes. It will also make manoeuvring around harbours, fjords and locks easier and safer.

Where conventional radars cannot penetrate, the radar will provide the highest possible resolution images in the vicinity of vessels and expand situational awareness.

The RS24 system is featured in Wärtsilä's InteliTug project, which combines technologies and digital solutions to develop a tug with autonomous navigation.

Images produced by the radar will be integrated with the onboard Wärtsilä Nacos navigational system for complete coverage.

The first orders for the system have been received and delivered, with installation planned on two cruise ships during the first quarter of this year.

Trials are also being carried out using the RS24 for wave detection purposes. If successful, it may have a significant impact on the future of passenger comfort. *NA*

The RS24 is intended as a navigational aid for smaller objects in congested waters

APPROVED redraws requirements for class verification

A joint industry project has developed a standard for sharing 3D models between shipyards and classification societies, ending the need for 2D drawings

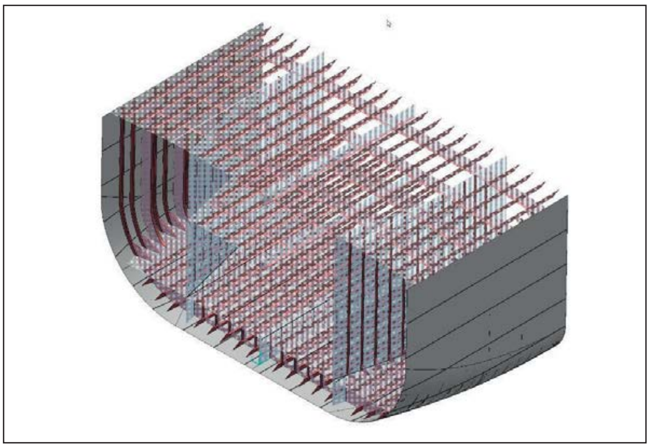
Modern ship design and construction is supported by a bewildering array of engineering tools, and no two companies are likely to adopt exactly the same approach. Added to this, is the growing requirement to support product lifecycle management (PLM) with supplementary engineering information that generates vast quantities of additional data.

Traditionally, CAD packages were deployed in the design and evaluation phases as a means from which design documentation could be produced. But as CAD has come to exist within a larger digital environment, with a flow of information between various systems, its tools are increasingly used as the method for recording product definition. The humble 2D drawing, once the simplest and most effective means of defining the product, has become increasingly superfluous.

Except, that is, in one key regard. Surprisingly perhaps, 2D technical drawings remain an explicit requirement when naval architects and shipyards submit their hull designs to classification societies, to ensure they fulfill both Class and Statutory requirements. The lack of compatibility between different software systems, not to mention the rapidity with which hardware, software and file formats can become obsolete, complicates the long-term accessibility and maintenance of those records.

Therefore, 2D drawings have remained the safest form of design documentation, with the class society then building its own digital verification model based upon them. Yet to all intents these drawings serve no purpose beyond classification. This process is enormously time consuming on both sides, given that with every design revision the society may need to re-verify.

Over the past 20 years there have been a number of unsuccessful attempts by the maritime industry to arrive at an open standard that would facilitate the data exchange of 3D ship models for class approval. One of the primary obstacles was that the different software vendors, understandably, were historically reluctant to cede any competitive advantage to their rivals.



Hexagon's Smart 3D is among the design tools that will be able to exchange data using OCX

The functionality of this software also differs enormously; no single product can perform all the desired tasks to an optimal level and naval architects and shipyards will typically mix and match different packages according to their needs at different points in the design process. Yet there is a growing realisation that standardisation is a prerequisite to digitalisation and allowing machines to speak to each other, something now being felt acutely in the development of other areas such as e-navigation and autonomous shipping.

Joint industry project

Conscious of this rapid evolution, and how shipping needs to keep pace with developments in the automotive and aerospace industries, three years ago DNV GL decided it was time for another attempt at finding a solution with a new joint industry project: APPRoval of Engineering Design models (APPROVED).

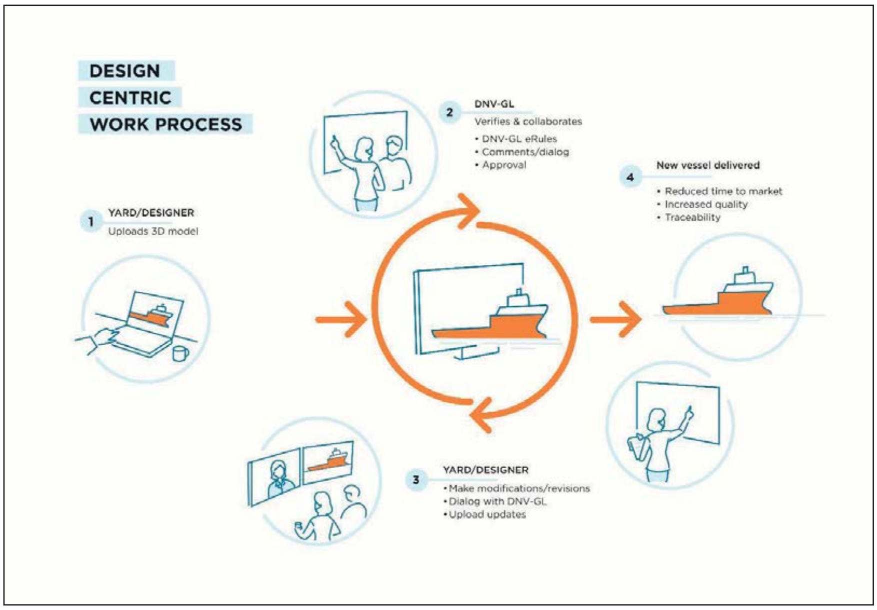
The project brings together expertise from CAD/CAM software providers Aveva, Hexagon (formerly Intergraph) and Siemens; along with ship designers and builders Kongsberg Maritime (formerly Rolls-Royce Marine), Ulstein and Chantiers de l'Atlantique; as well as 3D and PLM implementation specialists Digitread. The result of their combined efforts is the development of an interoperability specification that the partners hope will allow for shipbuilders and class societies to engage in complete sharing of the digital workflow using a common specification for 3D models.

"It's really a collaborative effort from the industry," explains Ole Christian Astrup, senior principal researcher, maritime transport, at DNV GL, who acts as the project manager. "When we started we didn't know whether it would be a success but are now attracting a lot of interest."

The key objective of the APPROVED project has been the development of a Digital Exchange Specification (DEX), or data schema, agreed upon by the project partners: the Open Class 3D Model exchange (OCX). Uniquely, OCX is said to specifically address the needs of the classification society and shipbuilders for fully digital information exchange.

Although ISO – in particular ISO 10303, the Standard for the Exchange of Product model data (STEP) which was developed in the 1990's – has led to some improvements in the sharing of simple CAD information, its focus is upon the asset to be built and it doesn't extend to a shipbuilding specific interoperability standard. However, the project partners believe that OCX could achieve this – if it can achieve industry consensus. Effectively, OCX acts as a conduit between the design tools and class confirmation tools, highlighting the structural information the class society requires and formatting it in a way that can be easily processed.

Astrup explains: "3D CAD systems have evolved tremendously over the last decade, and the vendors have put enormous effort into their performance and complexity. Technology wise the three software vendors who worked in the partnership – Aveva, Siemens and Intergraph – each have all the information that we need and have been able to resolve all our design requirements."



APPROVED will allow for a fully digital information flow between the yard and class society

Model-based definition

Building upon research DNV GL conducted into creating a model-based definition for shipbuilding, the partners began by determining the capabilities they wanted in the new specification:

- It should be a lightweight, CAD-neutral representation of the 3D geometry that can easily be shared
- Have the ability to carry both precise and approximate geometric positions, depending on how it is used
- Have expandable product definition information through the design lifecycle
- Be able to describe function and process related information
- Use multi-layered annotations that reference this function and process to the 3D model, and is robust to changes to that 3D model
- Be capable of catering for new function and process (meta)data as the need arises

These design assumptions dictated the structuring of the OCX content according to form, function and process. The physical properties, characteristics and geometry prescribed by the 3D model (the What), is just one aspect of this, to be cross referenced against the functional requirements and constraints (Why) and processes by which these will be managed (How). Meanwhile, the layering of the annotations will allow for a 'conversation' between the designer and class society to resolve any issues that may arise during the approval process.

"At the moment DNV GL has a typical verification process when we receive the design documents," says Astrup. "We will look at the drawing and do the necessary spotcheck calculations on problematic areas of buckling, stress and to ensure the designer has made the right assumptions about loads. If there's anything that needs to be corrected we will put a red mark on the drawing and send it back via our portal. The shipyard will then download the marked drawing, go to its design system and make the corrections.

"But in the future we envisage this will work much more seamlessly as we will have the dialogue directly around the 3D model, directly commenting and annotating it. The designer can then immediately pick this up on his design system and immediately see where the comment relates to, for example a stiffener, and make the necessary corrections. It will still be ultimately up to the designer to decide which actions we need to take, but he will immediately be guided to where the problem is and totally unambiguous what we're commenting on."

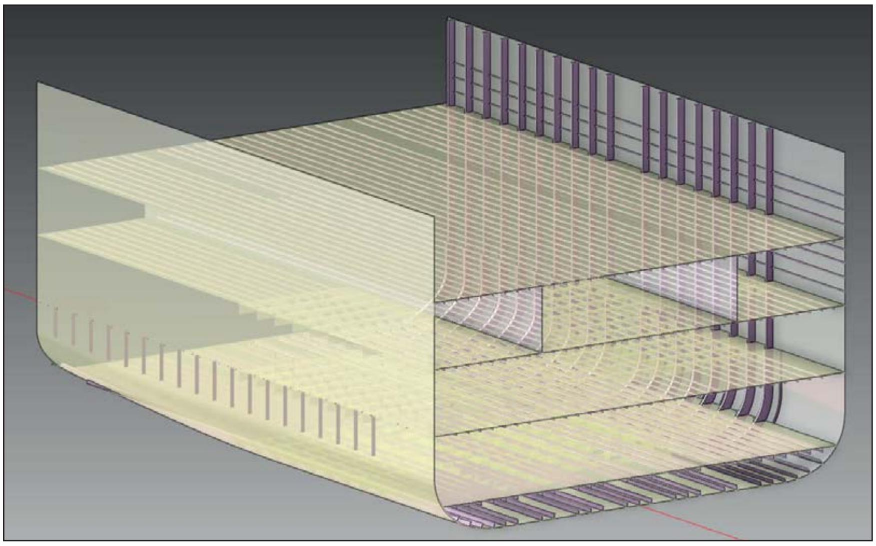
In the longer term the goal is to fully automate the approval process. If they should need to check anything, such as plate thickness, then the designer might upload their OCX-formatted data to an application programming interface (API) in the cloud for verification. When the final design is ready, the 3D model can be submitted and receive immediate feedback on whether or not it is compliant with class requirements.

Vendor collaboration

APPROVED would not have been achievable without the close collaboration of the project partners, in particular the three CAD software developers. Astrup says: "The other class societies ask us how we succeeded in bringing three major vendors together in the same room, agreeing on one neutral format. But it's simply a change in attitude. Going back 10 years they saw it as a competitive advantage to have something that was uniquely their own, but now the cost of shipbuilding and the waste of different exchange standards is simply too high to maintain."

Ken Sears, who liaised on APPROVED for Siemens, concurs, noting that interest in digitalisation has picked up in the marine industry in recent years and with this a "critical" need has arisen for common standards. "Setting the course for the marine industry means being able to look beyond our company to find, and define, ways to create a better future for all parties involved. This requires working with other industry leaders, some of whom happen to be our competitors."

Executive product director for Hexagon PPM, Mike Polini, says that previous



A 3D model created by APPROVED partner Kongsberg Maritime using Aveva's design tool, also compatible with the OCX standard

standardisation initiatives have faltered due to being too large-scale or 'point-to-point' solutions involving just a limited number of players. "These efforts were targeting the two-way exchange between 3D modelling tools – a much more complex problem than the scope of [APPROVED's] one-way exchange from a 3D modelling tool to the class analysis tools. One of the big drivers for this has been the shipyards and designers who stand to benefit from a more efficient and streamlined approval process."

Polini adds that APPROVED has tried to simplify the problem by limiting the scope of the exchange to an idealised, moulded surface and curve representation, with appropriate attribution to define the other necessary properties. Rather than presenting the problem as purely one of data exchange, it's the additional definition to process and workflow, that distinguish OCX from previous attempts at standardising data exchange, and open up the potential for a digital twin for class approval as the format undergoes further refinement.

Another of the project partners is French shipyard Chantiers de l'Atlantique, which sees APPROVED as contributing to its wider efforts to change the mindset of its designers from drawings production to data production, including providing its production teams with the capability to view 3D mockups on tablets and smartphones.

"As a shipbuilder, we expect to save man hours not only in drawing production, but also to be able to improve global lead time," says Laurent Cleuet, CAD systems project coordinator at Chantiers de l'Atlantique. "We also expect to improve the quality of review processes because we will be able to share the same model with all the relevant details."

Cleuet says that an internal evaluation concluded APPROVED could offer an "interesting" level of time savings, although in the overall context of structure design and workshop preparation this was comparatively modest. However, he expects further improvements to OCX will not only lay the foundation for a digital twin for the structure and hull, but that future iterations will be extended to detail outfitting (e.g. piping, cables and ducts) and share that information with the class society for compliance with regulatory requirements such as Safe Return to Port (SRTP).

Limitations of format

Of course, it is important to remember that OCX is intended as a lightweight format, and cannot in itself carry all the data required for the detailed design and production phases of a project. "The current standard is focused on exchanging the data that is required for class approval only, which has helped keep the standard easily implementable," says Sears, noting that it may prove inadequate if used for data exchange for other purposes.

The project partners have been eager to share the development with other design system providers, notably Napa, whose products are extensively used by many builders and designers during the early stages of a project. "I think Napa is the tool with perhaps the most complete suite of interfaces to different classification tools, where a common standard like OCX would save a lot of maintenance," says Astrup. However, given the commercial implications of a neutral format, which could prove hugely detrimental to vendors and shipyards/designers alike, ensuring the standard remains limited to the agreed parameters remains a concern.

Securing the endorsement of the other major classification societies remains the other major challenge, but Astrup is confident and says that progess is already well underway. "We've spoken to most of the major class societies and the reaction has been positive. This is an initiative they really appreciate and something that's been missing for a long time. The vendors don't want to keep maintaining an interface portfolio and have told the class societies this is something they would like them to support."

A number of pilot projects testing the process on real designs have already begun, with rollout of OCX as the basis for a DNV GL service expected to take place sometime in 2020. Yet while DNV GL has been the facilitator of the project, Astrup is keen to emphasise that its success is entirely down to the collaboration between the project partners and their various areas of expertise. "The vendors have the competence to support it from a technology base, but the designer and builder know how it can benefit their process."

Indeed, in that regard it seems only fair to give the final word to one of the partners. As a veteran of the earlier STEP initiative, Hexagon's Mike Polini knows better than most the pitfalls and challenges that can undermine the best intentions. "Working with our competitors to tackle a challenge facing the whole industry has been our guiding philosophy and allowed us to work on solving it as a team. It has built a camaraderie among the participants where we focus on sharing our successes rather than identifying and/or exploiting weaknesses. Because in the end we will all be better off if this project succeeds." *NA*

LNG positioned as 'greenest' marine fuel

A new study reveals LNG reduces shipping GHG emissions by up to 21% and defends it as a pathway to 2050

Tote Marine's *Isla Bella*, the world's first LNG-powered container ship

The maritime industry's feelings towards LNG have swayed between hot and cold since the start of the greening trend. While momentum for the gas has grown, so has the questioning of its long-term viability and the fight to determine whether it stands as the best investment option on the road to 2050.

Currently, there are over 30 LNG bunkering facilities worldwide and 143 LNG-fuelled ships in operation with another 135 on order. In 2017, there was only one functioning LNG bunker vessel, today there are nine. Despite this escalation in LNG related investments, some maritime experts and recent studies suggest that LNG is simply an interim fuel incapable of meeting the IMO's future 2050 targets.

A report released last month, however, backs LNG's role in improving air quality and revealed its ability to cut greenhouse gases (GHG) by up to 21% across the fuel's entire life cycle.

Commissioned by the not-for-profit industry group SEA\LNG and the Society for Gas as a Marine Fuel (SGMF), the study assessed the performance of LNG from Well-to-Wake – an approach which evaluates the fuel from production through to combustion – compared with conventional oil-based fuels.

According to the report, LNG can reduce GHG emissions between 14% and 21% in a slow two-stroke engine, which accounts for 72% of marine fuel consumed today. With a medium speed four-stroke engine, emissions dropped between 7% to 15%.

When examining the fuel with a two-stroke engine only during its combustion phase – Tank-to-Wake – GHG emissions were cut by up to 28% compared with heavy fuel oil.

The study investigated LNG's performance in the most common marine engines – two-stroke and four-stroke – but did not take the vessel type or conditions into consideration.

It also confirmed that emissions from air pollutants, such as sulphur oxides, nitrogen oxides and particulate matter, are all near zero in comparison to oil-based marine fuels.

Conducted by Thinkstep, a global consultancy company headquartered in Germany, and reviewed by a panel of independent academics, the study began in May 2018. Primary data on both LNG and HFOs during usage in marine engines was provided by original equipment manufacturers.

Although LNG proves to be a feasible solution for improving air quality and meeting the IMO's 2020 sulphur cap, it's still a long way off from significantly decarbonising or eliminating GHG emissions.

What role does LNG play?

"It will move the ball forward on IMO targets," said Pete Keller chairman of SEA\LNG at a press conference in London.

Keller, who is also the executive vice president of Tote – the first company to operate LNG-fuelled containerships – admitted that LNG may be an interim fuel but stressed its current importance as the only practical option on the market.

"It's the only alternative fuel solution that is available now," said Keller. "How long is it going to take to develop a viable, sustainable, scalable solution with some of the other alternatives being discussed? We can only sit here and say there's going to be a future magic elixir for so long."

The future of LNG

Although LNG is in plentiful supply and has a mounting bunkering infrastructure, which makes it one of the most readily available 'green' options, its long-term capability relies heavily upon future optimisations.

The degree to which LNG can reduce GHG depends upon the amount of methane slip incurred during the combustion process. But ongoing operational and technological advances could help enhance LNG's initial benefits, said Keller, therefore lengthening its lifespan and carving out a pathway for LNG to meet 2050 targets.

Manufacturers are currently improving engine designs and introducing solutions such as methane oxidation catalysts to mitigate methane leakages.

"There is a potential for reductions of up to 40% or even 60% by using catalysts", said Dr Oliver Schuller, the team lead energy and mobility at thinkstep.

SEA\LNG's study also noted the potential of bioLNG and synthetic LNG as a way of increasing emission reductions. It stated that "a blend of 20% bioLNG as a drop-in fuel can reduce GHG emissions by a further 13% compared with 100% fossil fuel LNG."

The group's next study will focus on what these different pathways to 2050 may look like.

"[LNG] is not the be all and end all, how far it will go and how long the path is until there are other opportunities, we don't really know," said Keller. *NA*

Norway is a maritime development superpower

Battery-powered ferries are proving the benefits of a cluster philosophy, believes the CEO of NCE Maritime CleanTech, writes Charlie Bartlett

The matter of tomorrow's fuel is far from settled, and it seems as though Norway has become the main battleground where competing technologies are fighting it out.

Hege Økland, CEO of the cluster organisation NCE Maritime CleanTech (NCE MCT), praises Norway's culture of "risk willing shipowners" who "like to implement new technologies", compounded by a forward-thinking government, which "actively incentivises new technologies".

"We are a small country with a small population but in terms of maritime development, we are a superpower," Økland says. "We can see this cluster philosophy working in practice."

Today, Norway has approximately 21 LNG-fuelled ferries in operation, which represents a considerable improvement on MGO in terms of emissions. However, the country's unique renewable energy infrastructure – whereupon around 98% of energy is generated through renewable resources, and overwhelmingly dominated by hydropower – means that running ships on battery power makes more sense than anything else. The Norwegian Public Roads Administration, responsible for Norway's transportation infrastructure, regards Norled AS's battery-powered ferry, *Ampere,* as a proof-of-concept. This has spawned a huge drive towards additional development in this area.

By 2021, 60 new battery ferries are expected to have entered operation. "It all started with *Ampere*, and this technology has now been proven," Økland says. "This ferry has led to a reduction in fuel costs for the shipowner. So it's good for business, not simply for the environment.

"Most of the electrical ferries in the world are in Norway, but we do see that other markets are coming up quite quickly. We believe it's important for us to help our partners enter new markets, and last month we had a delegation visiting

Hege Økland, CEO, NCE Maritime CleanTech

Seattle. They are also electrifying their fleet and wanted to learn from Norway."

Hydrogen momentum

Increasingly, movement is being made toward hydrogen, the entire world supply of which is currently derived from 'brown' sources such as steam reforming and coal gasification. But the Norwegian government anticipates that it will soon be able to generate hydrogen through renewable means.

"Hydrogen will be the fuel for several high-speed vessels come 2021," says Økland. "One of these will be operated just outside Stavanger. Fjellstrand will be building the ferry and developing the energy system. But we believe this is only the beginning, and we see that electrification is also entering many different market segments."

Another ongoing project for NCE MCT is the urban water shuttle, which comprises a fast aluminium ferry designed to replace or augment other forms of public transportation. The design is modular, allowing the ferry to be assembled from prefabricated aluminium parts, which can be altered according to the customer requirements.

"The urban water shuttle project started in 2014. At that time there was no demand for zero-emission ferries," says Økland. "This has been used as an innovation platform for various projects. Political decisions are drivers for innovation and this is a very good example how the Norwegian Public Roads Administration has used its procurement to drive development."

The shuttle's design has evolved over the years, incorporating the latest technology. It will be a fully-electric vessel capable of operating at speeds of 20knots for 1.5 hours without charging. NCE MCT calculates that the energy costs for this vessel will be reduced by 70%, not to mention the lower maintenance costs of electrical propulsion systems.

"We are now entering the production process," Økland says. "We are trying to reduce production costs by making it more modular. We have received funding from the EU, and on its completion this vessel will operate just outside Stavanger."

NCE MCT is currently investigating how to make the modules work in all climates, rather than being particular to the unique Norwegian weather, as well as researching other local and particular requirements.

Økland explains that NCE MCT is also conducting two studies that could eventually see the same type of vessel introduced to London and the inland waterways of Belgium; an initiative which could have significant implications for the future of Norwegian shipbuilding. "We have initiated this project since it was a concept developed by the cluster, and the county council will purchase this vessel and become the shipowner. We think this model will work not only in the high-end market in Norway but also in the Europe." *NA*

Direct current solutions are future proof, proclaims Yaskawa

The evolution towards multiple onboard power sources are driving demand for its DC-Hubs, says the electrical systems provider

Shipping is now at the stage where supply is being secured and low-sulphur fuels are being bought to meet the requirements of the IMO's 0.5% global sulphur cap, indicating shipping's reliance on a cheap, abundant and homogenous bunker supply is well and truly over.

Not only is the industry headed for a future where vessels will rely on more than one energy source on a macroeconomic scale but it becomes increasingly likely that individual ships will as well. Engines, whether burning conventional heavy fuel oil in conjunction with a scrubber, low sulphur gas oil, LNG, or one of the many untested fuels currently under discussion (e.g., hydrogen, biodiesel, and methanol), will form merely one power source, of many, on a ship.

But marshalling these various systems can be difficult, particularly if there are many different power sources feeding into, and power consumers drawing upon, the vessel's supply at once.

"In the future, more flexibility will be required," says Ville Parpala, director, product marketing of Marine Solutions, Yaskawa Environmental Energy (formerly The Switch). "Shipowners want to be able to adjust to different and new energy sources. Hydrogen is one of these megatrends that might come sooner than we expect. In China, they are building a fleet of hydrogen-operated vessels.

"Green energy sources – solar panels, wind, waves, hydrogen – provide direct current (DC) as an energy source. So, we are the enabler in connecting the power source to the propulsion with the DC-Hub. With this technology you can easily connect the fossil fuels with green energy sources."

Yaskawa's DC-Hub

Improving performance

Yaskawa recently partnered with Wärtsilä to equip three DC-Hubs on the offshore and subsea construction vessel, *North Sea Giant*. With the DC-Hubs, the vessel are capable of saving large amounts of fuel by changing the way the engines operate in dynamic positioning (DP) mode.

"Previously, the vessel had to run three engines at 20% load, which is, effectively, burning money," Asbjørn Halsebakke, Yaskawa's product and engineering manager, explains. "But using our DC-Hub in combination with a battery, we can power the whole DP3 system and hotel load with a single generator. No other vessel that we know of is capable of doing this. We calculate that by operating this way, the *North Sea Giant* could save 2 million litres of fuel annually."

The 0.1% sulphur cap of the Baltic ECA – the world's toughest – brings up the price of fuel. Meanwhile, icy conditions in the Gulf of Bothnia, the northernmost area of the Baltic, makes for a constant stop-start operation, wreaking havoc on the engines.

"Ice can cause major changes in propulsion speed," says Halsebakke. Powered by an engine while underway, the vessel switches to a shaft generator 'power-take-in' when in ice. Yaskawa calculates that the combination of LNG fuel and electrically assisted propulsion can trim CO_2 emissions by 50%, as well as cutting the cost of fuel and eliminating sulphur emissions from the equation.

In a separate project, the first LNG-fuelled bulkers – *Viikki* and sistership *Haaga* – were supplied with Yaskawa shaft generators as part of an integrated WE Tech installation to help the vessels meet their environmental obligations, even in the most troublesome conditions.

Next generation solutions

Now, the company is lining up a new range of products, dubbed Poseidon Power, to be released at Nor-Shipping. "The Poseidon drive is the next generation, we call it the fifth generation," says Halsebakke. "We are improving today's solution. Today we have a very compact drive, but we want to make it more compact than the DC-Hub solution we [currently] have. DC-Hubs are where we are going – standalone drives, that's old technology. We need to have a new solution that is future proof, that we can continue to develop.

"The market needs to be prepared for what's coming. If we look back 10 years, did we know that batteries would be so important? They were too big and too heavy. But look what we have now. So we need to be flexible enough to prepare for what may come in the future." *NA*

Test benches bridge the gap for Norwegian innovation

Norsk Katapult has developed an economical solution for demonstrating the viability of new marine technology concepts

Norsk Katapult interim manager Willie Wågen with Yaskawa's Asbjørn Halsebakke

Norway is famed for its clustering approach, with knowledge-sharing between large firms and smaller ones, even amongst rivals, ultimately contributing to the maritime industry's most advanced innovation economy.

But Willie Wågen, interim leader at Sustainable Energy Norwegian Catapult Centre (Norsk Katapult), believes that even with this supportive architecture in place, there are shortcomings that need to be improved.

"The way technology is developed there is quite good funding available at the concept phase and quite good arrangements for the market end of the journey," he explains. "But there is a gap between the concept and proving that concept.

"For example, when a company has developed a new solution, and needs to fit it into part of a system to see if it works, it is very hard for them to get this new technology installed onboard a ship. It has been left to the Siemens and Wärtsiläs of this world to do that."

The catapult centre, however, endeavours to change this by cultivating test-benches for new concepts to be proven in an inexpensive fashion. Since its establishment in June 2018, the catapult initiative has set up five different centres throughout Norway, from Stord to Ålesund. Each centre has a dedicated focus: robotics, digital (Digicat), ocean innovation (with a concentration on fish farming), sustainable energy, and future materials (including 3D printing).

"We make it so that you no longer need to buy the system. You can bring your component and rent a space in a testing centre," explains Wågen.

The centre where manufacturer Yaskawa (formerly The Switch) performs its own tests, using a variety of motors and mock-ups of offshore equipment, is one such facility companies can rent out. "Inside this building you have what is effectively a ship on land," Wågen says. "You have switchboards, systems and so on, and you can simulate a real ship operating. In addition to this, we will make a new test centre for synthetic fuels and connect it to this 'ship on land'. Anybody who has a fuel cell or an engine can come and test it here."

At sea, the catapult centre has testing facilities on an offshore wind turbine, a subsea installation and various active vessels, including: Solstad OSVs, Noled ferries, Knutsen OAS tankers and GANN passenger ships.

Other facilities include an electricity microgrid on a small Norwegian island, where tests are made using a variety of new sustainable energy sources. Catapult is also used as a vehicle to test prototypes in difficult weather, such as choppy waters or cold climates. Wågen compares the initiative to an Airbnb for new sustainable energy inventions, whereby testing and competence centres can connect with new companies. The otherwise clichéd comparison is more accurate in this case than most.

"We market and sell the testing centres – they will tell me what kind of equipment and facilities they have, and when it will be available," says Wågen. "But in a way it's better than Airbnb because the centres get support to redecorate the house – that is, winning government funding to help equip them."

Connecting these companies with the testing facilities is more cost-efficient for young companies than the former model – employed, for example, by various manufacturers of ballast water management systems in recent times – whereby a whole system would have to be purchased and installed in an in-house facility, simply to test a single component prototype. "[Now], you can just bring your component and rent a space in a testing centre," Wågen says.

One such outfit is electrical engineering consultancy Unitech Power Systems. "We have been delivering subsea distribution systems for many years now, but we want to divert into renewables," says Karoline Sjøen Andersen, a junior scientist at Unitech. "We want to use our experience in umbilicals to make power cables, a key parameter in the electrification of the ocean."

Unitech is now reliant on catapult centres for testing its new umbilicals, with the ultimate goal of producing a floating factory which will be able to spin cables on site, as required, from their constituent components. "So you have bundles of different subsea cables for different subsea facilities – electricity, fibre, whatever you need," says Andersen. "We want to have the whole supply chain in one place." *NA*

Innovating maritime simulations with wearable technology

A Norwegian joint industry project is rethinking maritime simulators with the help of Virtual Reality

Authors

Dr. Steven Mallam, Dr. Salman Nazir and Sathiya Kumar Renganayagalu
University of South-Eastern Norway

A student training with the Engine Room Virtual Reality simulator

Virtual Reality (VR) is a growing sector of the consumer electronic marketplace and has seen significant investment from the major global tech giants in recent years. As these technologies become more advanced and accessible, their real-world applications also become more feasible, opening new areas for use in maritime industries.

The InnoTraining project ('Innovating Maritime Training Simulators Using Virtual and Augmented Reality') is taking a new approach to traditional maritime simulators by developing VR Head-Mounted Display (HMD) based simulations for use in maritime education, training and operations.

InnoTraining is an innovation-based research and development project led by Kongsberg Digital and the University of South-Eastern Norway (USN), in partnership with the Institute for Energy Technology and The Polytechnic University of Milan. It is funded by the Research Council of Norway with in-kind contributions from Kongsberg Digital. This multidisciplinary project team has a broad range of expertise including: training, assessment, design, VR, human factors, and human-machine interaction.

Kongsberg Digital wanted to invest early in the research and development of VR HMD technologies for maritime simulation. "This innovative research development will put Kongsberg Digital in a strong position to address the demands in training of future maritime operators," says Stig-Einar Wiggen, the company's manager of research projects.

There are currently two VR simulators under development within the InnoTraining project. The first is on a virtual ship bridge, where students can learn to navigate ships with immersive VR simulations. The other is a more general ship safety simulator focusing on Fire Fighting, Search & Rescue (FFSR) training, which could provide more realistic and safe emergency preparedness training for seafarers.

Cutting-edge simulator development

The field of wearable technologies has evolved greatly over the past few years. Due to their ability to provide highly immersive and engaging experiences in a small portable package, VR based simulators are quickly becoming indispensable in professional training and education.

It comes at a point when the maritime industry in general is at crossroads, as the older baby boomer generation of seafarers are retiring and millennials are taking over their place. At the same time, seafaring competence itself is going through a change due to the industry's rapid digitalisation. These changing competence requirements as well as the incoming generation of seafarers, who prefer hands-on learning, have driven the industry to adapt new technology platforms for training.

A dynamic research program

To reach effective solutions it is necessary to have collaboration within the industry and InnoTraining is a textbook example of such a venture. The Training and Assessment Research Group (TARG), an academic team based at USN exploring the relationships between humans and machines, is working with Kongsberg Digital to take the first steps towards developing VR simulator training.

The new VR technology can facilitate simulator training at a fraction of the cost than might otherwise by required by large establishments for a simulator environment. Moreover, this form of training allows for a

The firefighting simulator is designed to provide more realistic emergency training higher degree of individual adaptation, which can make it more interesting and relevant for participants. The glasses also make the training feel more immersive and intuitive, so users can easily grasp the learning outcome.

The TARG members working on VR research include two associate professors, a PhD student and several Masters students, who are aiming to explore and analyse the various implications of VR technology in the maritime industry and make it more adaptive for training.

"We are confident that proper use of the new virtual reality technologies will enable better, more efficient and tremendously cheaper maritime personnel training," says Dr. Salman Nazir, the TARG leader at the Department for Maritime Operations (IMA) at USN.

Currently, the group's PhD and master's level projects are studying the performance of this VR simulator by investigating the training effectiveness, transfer, training motivation, user acceptance, and possible side effects of VR on users. The limitations of VR technology, for example discomfort and cybersickness, were not found to influence the training experience. In addition, TARG is examining the new performance assessment and active feedback possibilities enabled by VR technology, and their implications on training outcomes.

The research will result in new pedagogical methods and models in maritime training and education, enabled and enhanced by immersive VR. TARG's research findings already indicate that VR increases the intrinsic motivation of the students to train, while instilling higher confidence and self-efficacy. With the continuous improvements and evolving technology, the future for VR in maritime simulation training looks promising.


TARG researchers (left to right): Stephen Mallam, Sathiya Kumar Renganayagalu and Salman Nazir (Photo: Mehdi Poorniko)

Added value for ship design

Furthermore, VR provides new methods to both educate naval architects and assist in the development of marine structures. Dr. Steven Mallam, associate professor at University of South-Eastern Norway, explains: "The immersive first-person perspective of VR enables designers to experience and explore a ship, its layout, spaces and equipment prior to build."

Due to the realistic and true to size visualisations of designs, VR models could even be used for verification and validation of ship designs and structures long before ships are built. It also enables other stakeholders besides naval architects to be involved in the design process, providing tangible design input by experiencing the design in first-person. "VR is an exciting platform for facilitating participatory design processes by eliciting end-user knowledge from a variety of stakeholders. This could range from seafarers to shipping company personnel to future passengers and paying customers," says Mallam.

"For example, a marine engineer could put on a headset, experience their future working environment and provide input on design decisions that would improve their working conditions and work tasks. Similarly, if you are designing a cruise vessel, ferry or yacht, passengers and customers could provide input into the facilities and elements they would expect or desire for their onboard experience. VR can contribute in developing more user-centered ships and help catch design deficiencies early in the ship design process."

In addition to the design and simulation training applications, VR could be used for planning and in-situ training onboard before performing complex offshore operations. Combined with digital twin technology, VR has the potential to provide powerful visualisations and planning of operations.

The InnoTraining project will run until 2021. The research findings of the InnoTraining are already being disseminated throughout recognised international conferences and journals. The latest scientific findings from the project will be presented at the TransNav conference this June. *NA*

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The balance of power

Corvus Energy's latest load-levelling storage system, to be delivered to four Havila Kystruten ro-paxes, will be the largest battery installations to date, but the company is planning a leviathan of a successor

Havila Kystruten's hybrid ro-paxes will be delivered in 2021

The incredible efficiency gains of load-levelling – drawing a constant input of energy from the engines and using a battery to compensate for the rising and falling needs of the propulsion system – are being realised throughout Norway. But in March, Corvus Energy was contracted to provide a large energy storage system for Havila Kystruten's four ro-pax ferries, which will travel between Bergen and Kirkenes, on the Norwegian coast.

With 6MW of capacity, these batteries will be far larger than what is needed for load-levelling, therefore, their power can also be used for other purposes. Recent legislation by the Norwegian government has declared that from 2026, only non-polluting vessels may enter the Geirangerfjord and the Nærøyfjord. This means that vessels must not emit anything into the environment, including CO_2, effectively prohibiting the use of engines anywhere along the route. But using battery power in combination with electric propulsion, comprising of Rolls-Royce Azipull and Tunnel Thrusters, the new ferries will be able to sail the fjords while running no engines and emitting no exhaust of any kind.

The rest of the time, they will be able to run on their Rolls-Royce Bergen LNG-fuelled engines at their most efficient setting – around 70-80% load – charging the battery and ensuring a highly efficient operation. By operating in this way, around 20% overall fuel efficiency is available while underway.

Although Corvus claims these will be the biggest battery installations in service, once completed in 2021, they won't remain that way for very long. With a growing number of larger newbuilds now incorporating battery packs, charging facilities at shore are becoming more prevalent – especially in Norway, where clean hydroelectric power is abundant. When the 2020 sulphur cap comes into force, the price of many fuels is expected to increase, and the relatively inexpensive electricity supply from shore is coming to be seen as a way of offsetting the cost of voyages.

From Orca to Blue Whale

At the Nor-Shipping trade show this year, Corvus will release Blue Whale, a much higher-density energy storage system than Orca ESS, which is the system due for installation on the four Havila Kystruten vessels. In practical terms, this means that a Blue Whale installation can pack power into a space around 60% that of Orca.

There is one very important reason for this: discharge rate. An Orca battery cell can discharge all its power at a rate of 3C, emptying itself in the space of 20 minutes. This is handy for tugs, ferries and OSVs, which might need a large amount of power in a hurry, but it also generates substantial amounts of heat and incurs much higher maintenance requirements on associated systems.

However, this is the case with Blue Whale, which has a discharge rate limited to 0.5C. "So if it is a 12MW battery, it will be able to deliver 6MW in an hour," explains Halvard Hauso, Corvus's executive VP of sales. "Because the battery pack is so large, there will not be so much demand to take all the energy out in such a short time – you're going to use it for a very long time.

"This means much less weight and less cost because of the C rate. What we have generally seen, in terms of in our projects is 0.1-0.2C. That means the heat coming from this is next to nothing, and if the temperature ever gets too high, the cell will be disconnected."

It also means that less space needs to be given over to maintenance requirement for the cells, allowing more to be packed into a smaller area. "The product is a huge module stack, and these are specially made for transportation, installation and operation on a cruise vessel," says Hauso .

His example system is a "small" installation of 12MW, double the size of any installation to date. But the dimensions are considerably less than that of an equivalent Orca system. "It would save around half the space," he says.

"If you come to a port where there is no shore power, you can stay there for several hours with zero emissions. Of course, the much larger vessels, like Royal Caribbean, that's not where we're going to start. The small to medium size cruise vessel segment is where we see this being applied." *NA*

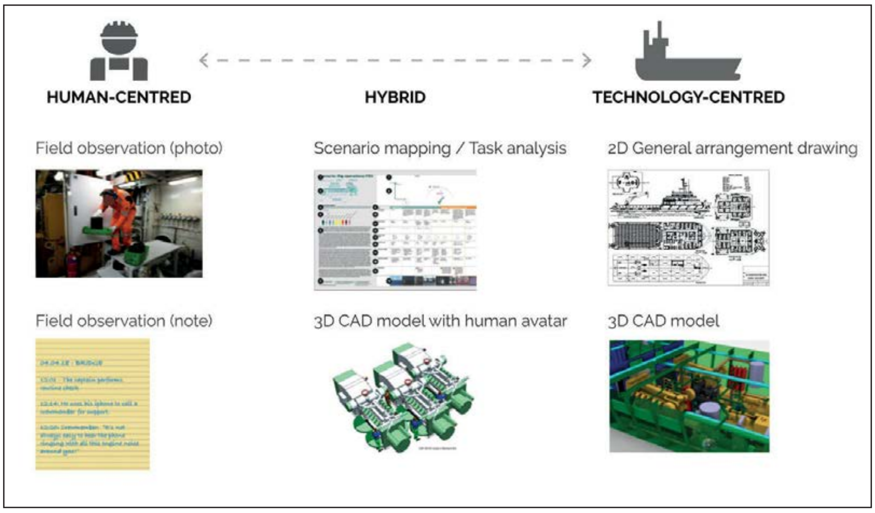
Connecting maritime operations to naval architecture

How to help ship designers observe, analyse, and work with the operational experiences of ship crew? The ONSITE project created a detailed process and methodology to bring field studies onboard ships to the core of the ship design process

The human element is the major source of risk to safe operations. Human errors are generally caused by technologies, environments and organisations that, in some way, are incompatible with optimal human performance. Safer, greener and more efficient operations are achieved through design processes that take the entire operation into account, including the human element. To achieve this, the industry needs designers who are aware of and trained in acquiring and applying operational field knowledge.

A common practice is to involve captains or chief engineers in ship design meetings on shore. The problem is that the captains and the designers do not have the same understanding and representation of the ship, and of its operation. As a result, the captains might not know the information the designers need, nor how to share it with the designers, and the designers might not know what information they can obtain from the captains, nor how to capture the information they need. This is especially the case with complex ship operations. For ships with relatively simple operations, the size of the ship crew tends to be reduced to the absolute minimum, which creates complex work tasks for each crew members.

The other way to close the gap between design and operation is to send ship designers onboard a ship to perform a field study. In this case, the ship designers can experience the conditions in which ship crew live and work. They can discuss new design ideas with the crew and get instant feedback. They can gather data about the systems, work tasks and crew experiences that they would not have been able to gather otherwise. As such, field studies play a critical role in acquiring contextual, systems-oriented and human-centred knowledge about demanding maritime operations.



Human-centred, technology-centred, and hybrid ship representations

Field-driven ship design

The Ocean Industries Concept Lab from the Oslo School of Architecture and Design (AHO) teamed up with NTNU, DNV GL, Pon Power and Ulstein to lead the research project, ONSITE, from 2016 to early 2019. Now concluded, ONSITE's findings highlighted the challenges of trying to close the gap between operation and design by use of field studies.

ONSITE started with an analysis of the barriers to implementing field studies in ship design processes. The first barrier is the perception that field studies require too much time and are resource demanding, outweighing their potential benefits during the ship design phase. The second barrier is the difficulty of connecting human-centred, operational field experiences with technology-centred, architectural needs of the ship design process.

Ship designers analysing their knowledge of ship operations before a field study. Operation mapping (bottom right corner) is used together with a general arrangement drawing (centre)

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"On the one hand, the ship can be seen and designed as a floating environment where the ship crew live and work. On the other hand, the ship can be seen and designed as an assembly of a hull, engines and other systems," says Etienne Gernez, a researcher at AHO. "The two perspectives need to be combined: ship systems need human operators to use them and operators need ship systems to execute most of their work tasks." Instead of spending time discussing the potential cost-benefit of field studies, the ONSITE project partners jumped straight over the first barrier and set to work integrating field studies into ongoing design processes.

Based upon three case studies, ONSITE resulted in three contributions:

1. A process that helps ship designers scope, plan, execute and debrief their field study in the most efficient way, minimising the time spent on the ship while maximising the quality and relevance of the data collected.
2. A framework that connects human-centred, operational field data with technology-centred, architectural data that designers can work with ashore.
3. A software prototype that helps designers sort, structure and archive their field data, making it ready to use by other members of the design team, for immediate or later use.

Per Olaf Brett, deputy managing director and vice president at Ulstein International, is convinced of the benefits, stating: "From now on, we will never start a new design process without using the ONSITE approach. The cost is not an issue because we see that field studies have a value throughout the whole design process downstream. ONSITE is probably one of the most important projects Ulstein has been contributing to in the last five years in terms of operational, hands-on value."

Case study: designing for service space in ship engine rooms

ONSITE field studies always begin with an analysis of the needs of the designers involved in the ongoing ship design processes, in order to find out what field data is the most relevant to capture. The first ONSITE case dealt with the design of ship engine rooms. The goal of the field study was: How can we design for better experiences of the users of ship engine rooms?

The field study took place on a platform supply vessel designed by Ulstein with an engine room designed by Pon Power. The field observations focused on:

1. The tasks performed by the crew in the engine room during the supply operations of the ship.
2. The systems used to perform these tasks.
3. The experiences of the crew when using these systems.

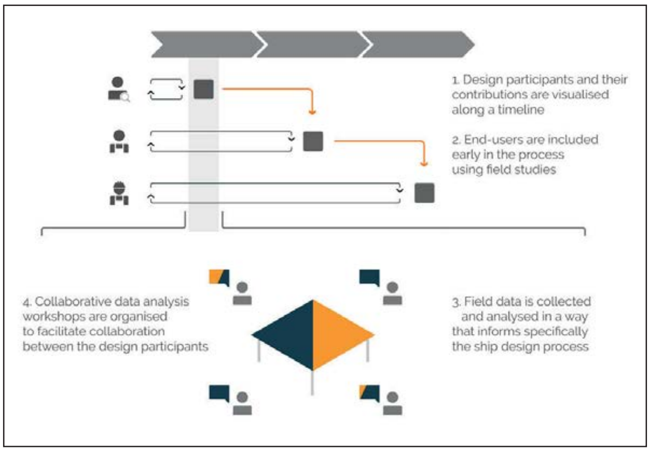
Two main problem areas were identified as a result of the field study observations:

1. The engine as a working place: The engine needs to be seen as the central element of a working place where human operators need to regularly carry out work tasks, such as service and maintenance tasks.
2. Engine integration in the engine room: The engine's integration into the whole engine room needs to enable the human operators to carry out their work tasks in the safest and most efficient way.

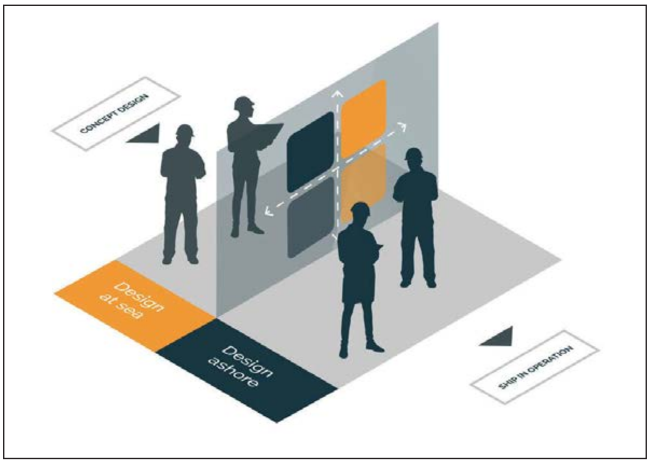
ONSITE field studies are followed by a 'collaborative analysis workshop' where the project stakeholders review and work with the field study findings. The insights gathered from the workshop are added to the field study data.

AHO facilitated a workshop with Pon Power and Ulstein to explore their own experience in the design of engine rooms and their integration into the overall ship design. Design problems that repeatedly came up during the design of engine rooms were identified, as well as opportunities for addressing these problems.

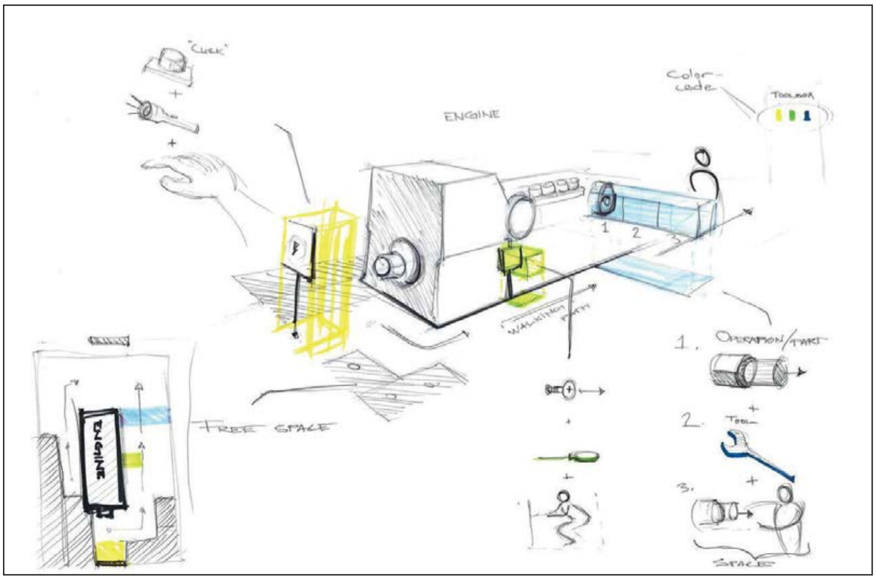
There were two main outcomes of the workshop. First, Ulstein and Pon Power's designers reached a common understanding of the engine room design requirements, seen from the perspective of the end users. Second, the participants developed a concept for a collaborative design process that would capture the end user requirements.



From the observation of a workplace to the design of a workplace



The connections generated by field studies: design process steps, design activities from different design traditions, design activities taking place at sea and ashore, human-centred and technology-centred design data and ship representations



Example of concept sketch used to analyse field study findings and propose new ideas. Concept and visualisation by Jon Fauske (OICL)

In the ONSITE process, the workshop is followed by prototyping sessions. AHO went back to Pon Power's office to prototype the concept. One of Pon Power's service mechanics was filmed while he performed service interventions on an engine. He was asked to perform the same service interventions that were observed during the field study, and to explain in details what were the critical steps of the different interventions. The space required around the engine to perform the interventions was measured. This enabled to document in video and then transfer onto a 3D CAD model how different service interventions are done, what tools are used and what space is required around the engine for the crew to work under safe and optimal conditions.

The concept of human-centred engine rooms that was developed in this case has the potential to enable more efficient maintenance and service interventions for the end users of the engine rooms, which reduces the risks of injury, system failure and operational downtime. The field-driven approach also has the potential to improve the detection of design flaws early in the design process, and consequently, reduce the risk of additional design iterations to correct these flaws.

The design case enabled each company to stimulate internal and external collaboration. With Pon Power, we connected a service mechanic with a 3D modelling engineer, a yard supervision engineer and the technical director. With Ulstein, we connected concept engineers working with machinery and hull design with engineers working with detailed ship design. Last but not least, we connected all these design stakeholders together with the end users of their design artefacts.

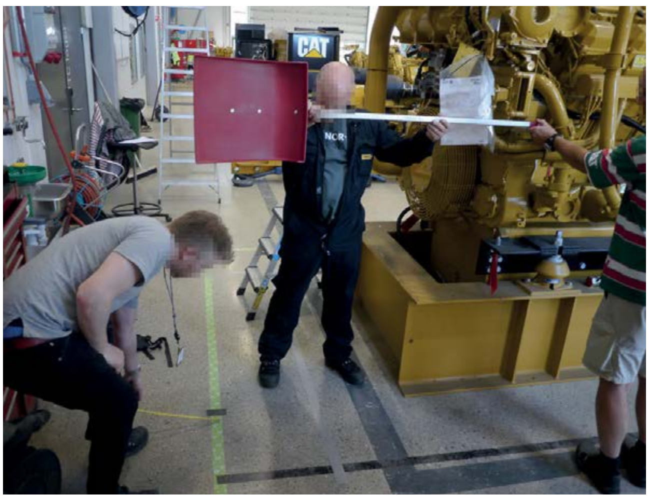
"ONSITE has also focused on our responsibility we have for the people who will install, use, operate and maintain our ship engines in modern ship designs. We have improved how we can integrate this responsibility in our design and assembly processes," says Øystein Skår, technical director for PON Power.

How to link ship architecture and maritime operations

ONSITE researchers analysed the published literature about ship design processes and found that ship designers traditionally focus on the ship and the ship systems from a technological, ship-centric perspective. To support the implementation of a human-centred perspective that focuses upon how ship crew actually use the ship and the systems designed for them, ONSITE researchers developed a framework in which design activities that combine a technology-centred perspective on ship systems and a human-centred perspective on the use of ship systems can take place.

This resulted in the Operation-Architecture, or OPAR framework, where ship design is modelled as a concurrent exploration of the operation of the ship (how the ship is used) together with the architecture of the ship (what the ship is made of). As such, OPAR places the human-centred representation of the ship operations next to the technology-centred representation of the ship, and proposes design activities that connect these two representations. The design activities in OPAR have the following functions:

- Facilitating the collaboration of the different participants to the ship design process (e.g. collaborative data analysis workshop)
- Observing and documenting end-users' experiences in their context of use (e.g. field observation, interviews, layout mapping, scenario mapping)
- Analysing field observations (e.g. task analysis, function analysis, system mapping)



Enacting service interventions on an engine with a mechanic, using props to represent engine parts

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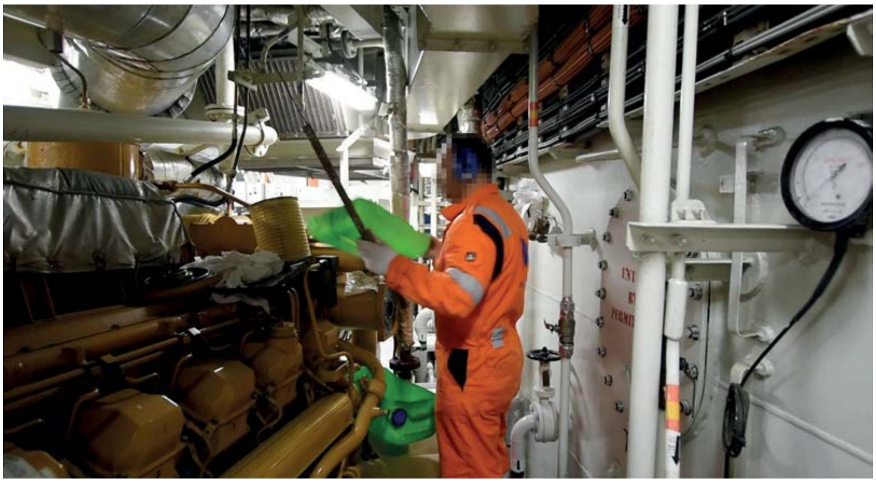


Example of finding: there is no work surface designed for engine service work tasks. The mechanic needs to put the tools and parts required for the service task directly on the engine. In addition, the mechanic had to build his own tools, a stick and a green jerrycan to collect used oil filters, to help him perform this task

- Generating and evaluating operational and matching architectural concepts (e.g. paper sketching, paper mock-up, video enactment of operational scenarios combined with 3D CAD modelling)

OPAR can be used in a variety of types of design problems, including:

1. Retrofitting new systems into an existing ship to check if the new systems require a change in their operational procedures. Conversely, the designer can start with the analysis of the current operation of the ship and use it to select a specific system that allows the operation to be performed in a better way.
2. Repurposing a full ship: the ship designer can check how different operations can be implemented using the existing ship architecture, or if the architecture needs to be modified to perform the desired new operation.
3. Designing remote-controlled/autonomous ships: the ship designer can explore operational scenarios and technological solutions that are not yet well known. For example, the operation of the ship might not be spatially constrained to the ship, with ship control centres being placed ashore. When removing the humans from the operational equation, the designers need to analyse what human operators do and how they do it, in order to derive what can be automated, and how.

ONSITE researchers observed that designers who worked with ship workplaces and end user experiences were encouraged to think about their own experience as designers and how their work might impact the experiences of the end users. This can help ship designers augment their design repertoire, and tune their design judgement towards design decisions that better prioritise what the ship architecture needs in order to enable an optimal operation of the ship.

Towards digital field study tools

Field studies generate data that ship designers don't usually deal with. ONSITE has documented what type of data is created and has proposed strategies to manage it and use it in ship design processes.

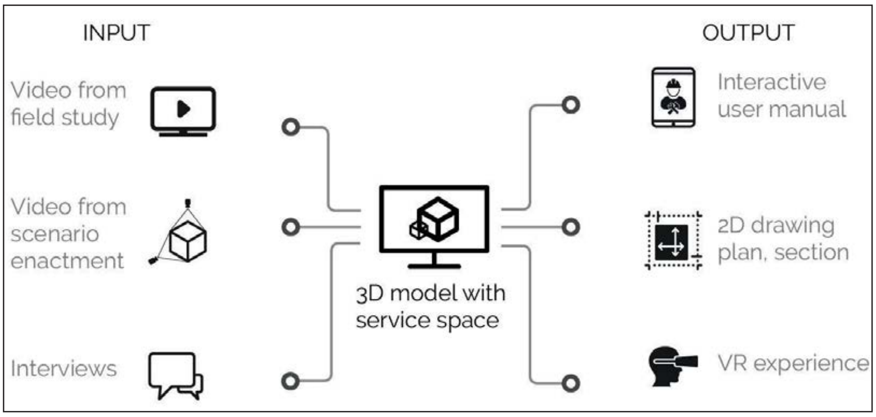
The goal is to build a database that can be used across field studies and across design projects. Building the database should be efficient and effective. One example of a gain in efficiency is to shorten the time required to process the data. Effectiveness is related to how useful field data can be and its analysis when injected into the design process.

As such, it is critical to ensure that all the field observations and reflections are logged in the database. The data most relevant to the design process at hand should be properly flagged as an idea, a problem, or a question which can be explored further by different users of the database.

ONSITE researchers have designed a data architecture that keeps track of the field data and the metadata (when it was produced, by whom etc.) and ensures consistency in data types. The architecture is built upon elementary units of data or "data atoms" that all share the same attributes. Each data atom may be a photo, a drawing, a video clip, or a piece of text.

With a data architecture backbone in place, ONSITE researchers have explored what types of digital tools could support field-driven design processes. They have prototyped a user interface concept that makes it very fast for a field researcher

Example of observation from a field study: a mechanic changing an engine oil filter. While carrying used oil filters dripping with oil, the mechanic needs to climb stairs and to bend over to avoid a beam on the ceiling. This is just one example of many challenges during common work tasks in a ship engine room



Inputs and outputs for a concept of a 3D model that visualises service space

to write up hand notes from the field and upload the media collected while in the field. The user interface also allows for fast and efficient data flagging and tagging according to its relevance for different projects.

Each data atom can be enriched by annotations and additional content added by multiple users at multiple times, thus strengthening the connection of each data atom to ongoing and future design conversations. The overall quality of the field database comes from the quality of the design conversations built upon the use of the data base, which relies on the quantity of data atoms and their individual pertinence. Commercialization opportunities for the digital field study tools are currently being explored, with the objective to make the tool free for educational purposes.

For more information on the Ocean Industries Concept Lab and maritime research taking place at The Oslo School of Architecture and Design, please visit: https://medium.com/ocean-industries-concept-lab

About the author

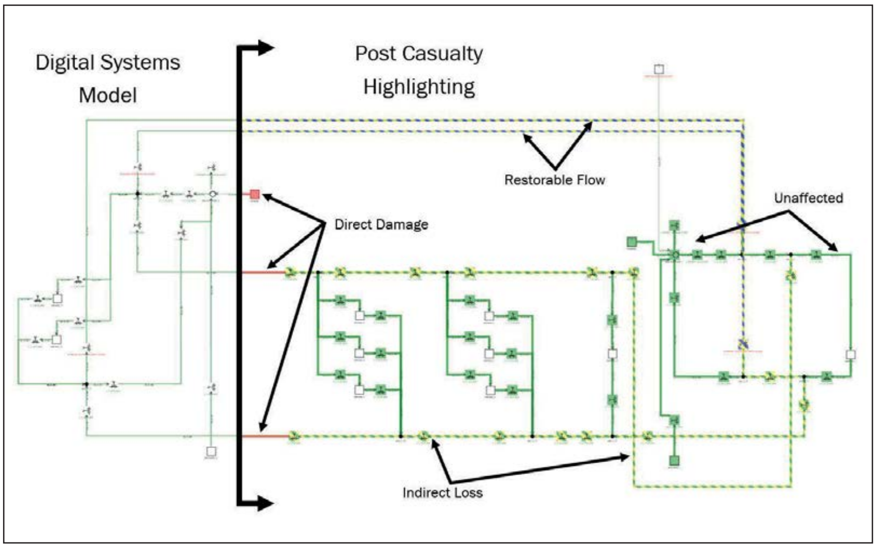
Etienne Gernez is a researcher in the Ocean Industries Concept Lab at the Oslo School of Architecture and Design. Etienne is trained as a numerical modelling engineer and has been working as consultant engineer in an international, maritime consultancy company. Etienne has experience with multi-disciplinary projects related to ship design and ship operations, and innovation in the ocean industries. *NA*

Safer systems design needs joined-up thinking

Alasdair Douglas, Associate Naval Architect at Brookes Bell, makes the case for digital systems modelling for the lifetime of a vessel

With the introduction of Safe Return to Port (SRTP) in July 2010, ship systems are now designed and assessed to ensure they meet the minimum level of availability outlined in SOLAS. This assessment is extensive, requiring consideration of many interdependent systems subject to a range of casualty scenarios.

On the operational side, the regulations require vessels to be able to restore system functionality within an hour of an incident. In October 2018, the Bahamas Flag published an instruction notice providing more detail on the operational requirements. The cruise industry, both operators and shipyards, is still evolving its response to meet the regulatory requirements.



A digital systems model in Systema

We believe that it's time for the industry to shift its methodology of verifying system redundancy away from a traditional Failure Mode and Effect Analysis (FMEA) approach. Instead, it should focus on the creation and maintenance of a digital system model, which understands both the logical dependencies of systems and the location of each system component on the vessel.

A digital systems model can provide many advantages over the traditional approach. The owner and shipyards can be confident that a thorough analysis has been undertaken on the system design and that all system interconnections have been included.

Furthermore, changes to systems or vessel layout can easily be included in the model to investigate what-if scenarios and to re-verify compliance efficiently. Lastly, updates to manual actions can be determined automatically through a programmatic approach and new documentation produced for the operator to use.

In the same way that vessel stability is verified and maintained through a digital model throughout the lifetime of the vessel, system design and verification can now be approached in the same way ensuring lifetime compliance.

Traditional FMEA Approach

At the design phase, approaches to redundancy such as duplication and separation are considered and used to determine the overall layout and principles that must be applied during the design of the systems. Ensuring systems adhere to these principles can be time consuming and requires constant monitoring, concluding with an assessment to ensure redundancy is met and the restorative actions determined where necessary.

This can be carried out by means of a FMEA, which is labour intensive and relies on manually reviewing all system diagrams and creating significant amounts of documentation. During this process, it would be impossible for all potential system interconnections to be fully analysed in such a manual way.

FMEA approach takes a top down approach, in which high level redundancy principles are set out on a system-by-system basis. It is done once, at the end of the design and only for the purpose of certification. The process does not provide the ongoing benefits which a digital systems approach can provide.

A verifiable single source of system data

When designing and assessing ship systems, the information required comes from many sources. This poses a challenge simply in terms of data management to ensure information can be passed between teams easily. By developing a digital model of the systems, it brings all the information together in a coherent data source, which can then be queried and audited in a single, consistent manner.

In its simplest form, the systems model could simply contain information such as the location of components and the routing of pipes and cables. This provides a definition of the systems geometry and topology which can be used as a means of checking locations against the redundancy principles.

It can also form the basis of audits carried out during the build process by the yard, or commissioning when the operator will want to have a clear understanding of the location and routing of major components and connections.

A repeatable methodology

The systems model should not be limited to simple topology but include the functionality and interdependencies of the systems, thus allowing availability and redundancy to be assessed through calculations. An automatic calculation process provides a comprehensive analysis in which all subsystems and interconnections can be considered simultaneously, but crucially are a repeatable and verifiable methodology, making it an ideal solution for all parties involved.

From the perspective of Class and Flag, a calculation-based assessment allows the approval process to focus on the validity of the model and not the correctness of the methodology. This reduces the requirement on the persons approving to have a deep understanding of all systems and their redundancy principles and instead concentrate on checking items such as locations of components and routings of connections.

The owner/operator will benefit through increased confidence in the delivered vessel and a reduction in the requirement for their teams to be heavily involved in the review and approval of documentation during the design and build.

Casualty-by-casualty

A digital model of the systems allows the designer to tackle the problem in a system-by-system manner, while modelling interconnections between systems to generate a fully connected model.

Although the model is built from a system's perspective, it can also be readily assessed on a casualty-by-casualty basis, allowing the specifics of individual damage scenarios to be visualised and well understood. Such an approach is not feasible when the assessment is a table top exercise as the number of scenarios considered for a vessel may exceed a thousand.

However, with an automatic calculation, the only consideration in adding additional casualty scenarios is the computation time required, which is much more cost effective than a manual approach.

Automatic generation of crew manual actions

One of the key outputs of the assessment process are the manual actions required to maintain systems availability, which form the basis of any crew response. It is vital that there is both confidence in the actions validity and that they can be kept to a minimum, especially when considering the additional one-hour time limit stipulated in the SOLAS SRTP requirements for all restorative actions to be completed.

A functional systems model allows the manual actions to be determined automatically by computing the steps required to reconfigure a system to restore availability. This can significantly reduce the work involved in determining these actions which would require the use of FMEA across several disciplines.

Interdependencies between systems are considered automatically through the digital model and the entirety of all actions required is known, providing a clear understanding of the effort involved in restoring all systems. By using the casualty-by-casualty approach, the actions can be determined on a per casualty basis, giving the most accurate and concise set of crew manual actions to use for crew response.

Compliance during operations

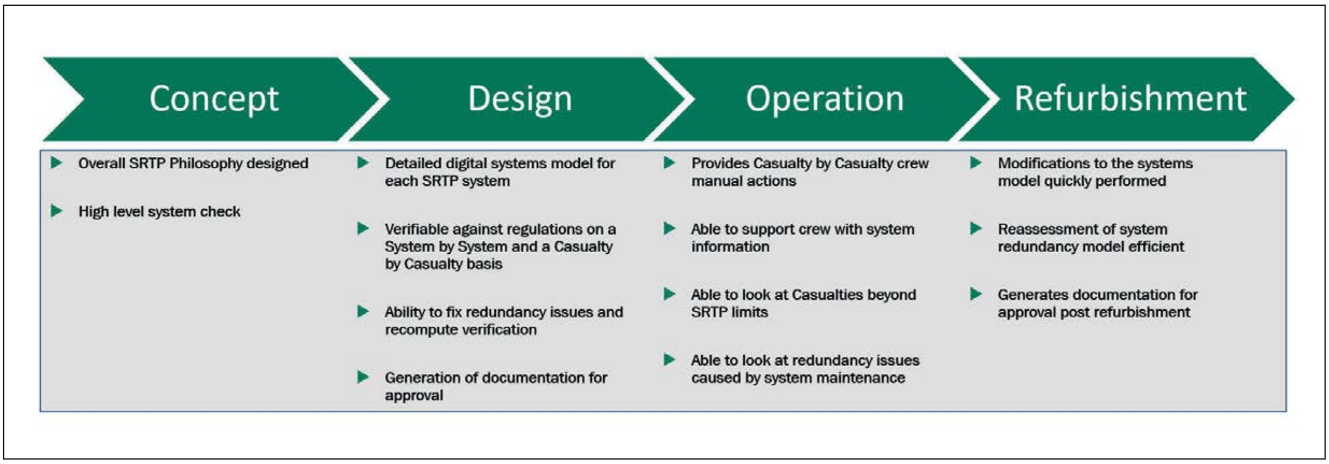
The onboard response to a SRTP situation can be aided with the use of the digital model, providing the required set of actions and allowing alternatives to be considered, something that cannot be dealt with through paper-based assessment.

During the design and assessment process, actions are generally developed based on the normal operational state of the system, such as the expected configuration of valves, circuit breakers and other key equipment. While operating, it is not unusual for equipment to be taken offline for maintenance but in terms of the SRTP response, the unavailability of a bilge pump could in fact break the redundancy principles and the crew manual actions are no longer valid.

It is possible to consider the availability of crew manual actions beyond the normal operational configuration either through pre-calculation of alternative configurations or having a live systems model that is fed information regarding the current system configuration.

On one hand, this could provide an alternative set of actions to maintain availability, or it could highlight when

The value of a digital systems model throughout the lifetime of the vessel

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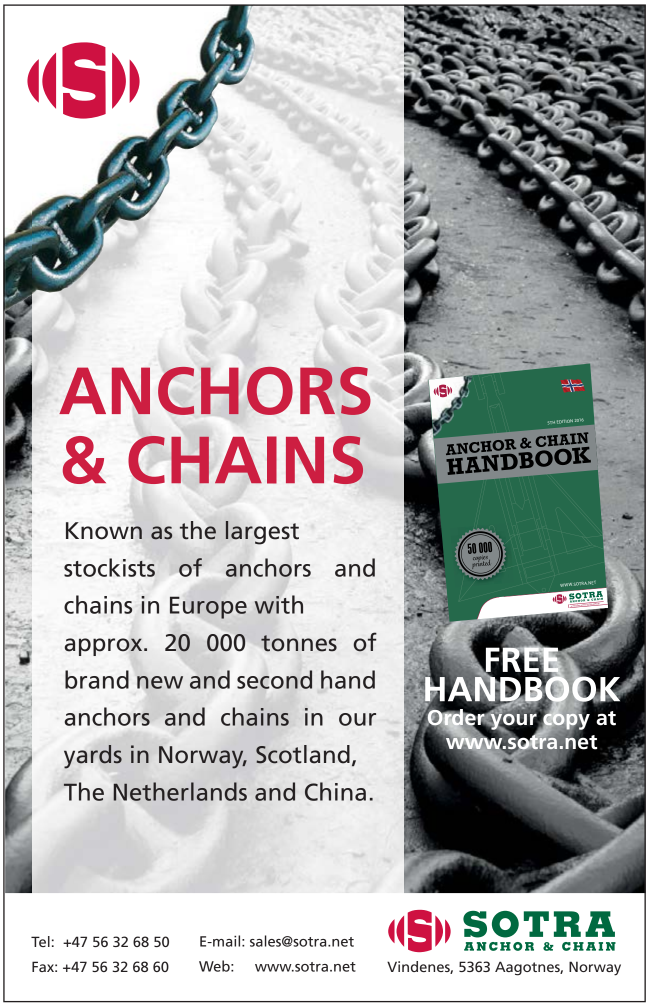
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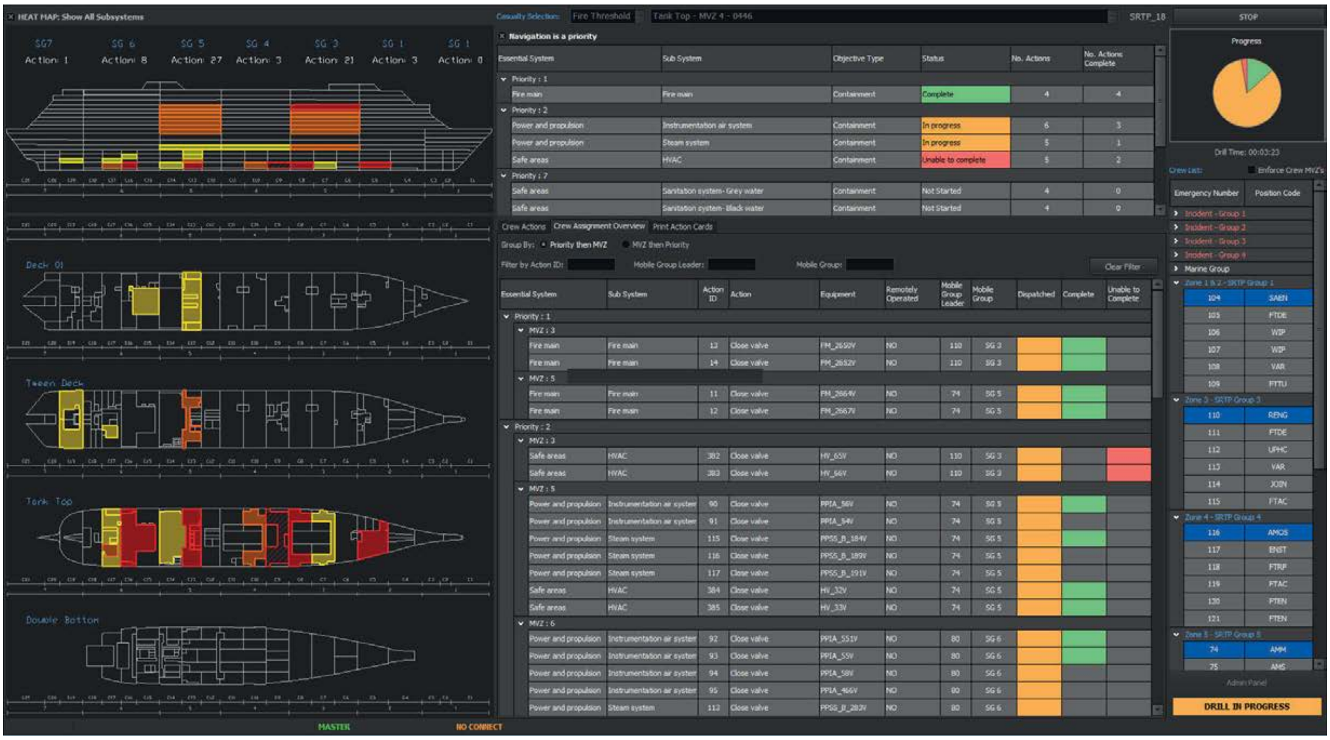


Supporting crew training and response with SRTP onboard during operations

SRTP compliance is no longer possible, something that is equally useful for the crew to understand. This allows the operator to identify scenarios, such as routine maintenance, that could negatively impact the SRTP compliance, and thus put procedures in place to deal with it.

Through-life compliance

One of the challenges facing operators is the requirement to maintain the SRTP compliance throughout the operational lifetime of a vessel, through crew training and the process of ensuring that changes to systems are considered.

It is common for vessels, especially cruise liners, to go through refits and revitalisations, a process which may require changes in vessel layout and/or systems themselves.

Currently operators are faced with the possibility that they may need to have system designs reassessed, documentation updated and reapproved, with crew responses modified accordingly. This is a significant task if the original assessment was carried out as a paper-based FMEA exercise.

With the availability of a digital systems model this task is significantly reduced. Changes to either the vessel layout or the systems can be easily and quickly incorporated, and the redundancy and availability reassessed with the click of a button.

Furthermore, any changes to the crew manual actions can also be automatically re-generated as part of this process, allowing the crew response to be easily updated while also ensuring confidence that the changes proposed do not infringe SRTP compliance.

Embracing the benefits

Ensuring SRTP compliance at the design phase is currently a lengthy and complex process. Once a vessel is in operation it is necessary to continue to prove compliance through crew drills and updated documentation. Managing this through paper-based assessments is possible during the design but it becomes increasingly burdensome as the vessel ages and modifications are made to vital systems.

A digital model provides a rigorous and repeatable assessment at the design stage and is an efficient and effective way to ensure compliance through a vessel's lifetime. Digital models also provide information beyond SRTP compliance that consider more extensive casualty scenarios or system configurations beyond normal operating states. This enables operators to analyse the criticality of certain items of equipment which in turn can be used to understand the impact of, for example, maintenance work. Maintenance activity can then be planned to minimise the impact on system availability during operation.

A software product, such as Systema, is capable of modelling and analysing ship systems for redundancy to ensure compliance throughout the lifetime of a vessel.

Through the modelling of systems and the ability to import information from existing sources, systems can be created, interconnected and analysed, and actions generated in line with the SRTP regulation. Proposed system changes can also be easily assessed. The output can be actively used to support the design of the systems, the approval process, and the development of the crew response actions.

A digital system model turns what is now an onerous process into an effective and streamlined process which can feedback into the design process rather than simply being a compliance burden, ultimately increasing the overall safety of the vessel. *NA*

A smaller slosh

Experiments undertaken by the University of Southampton reveal the installation of baffle systems in cruise ship swimming pools could alter water motion, improving safety and stability

Sloshing is defined as the motion of any fluid inside a container. This is caused when partially filled tanks are excited at certain frequencies [1]. On cruise ships, sloshing effects are an issue present in swimming pools [2]. Free surface water motion in swimming pools onboard cruise ships can cause passenger discomfort, wet decks and ultimately stability issues [3].

With the rapid growth of the cruise industry and bigger pools, sloshing has become a considerable problem in the past few years. As a result, there is significant interest in improving swimming pool design, thereby ensuring safer operations and greater customer satisfaction rates. Current pool design onboard cruise vessels show a deeper than desirable depth in order to reduce the tuning of the pool's natural frequency with the ship's response.

Cruise ship swimming pools are getting bigger

Research undertaken at the University of Southampton has explored non-intrusive methods of reducing sloshing in swimming pools onboard cruise ships through experimental testing. Moreover, it aims to create an experimental test method suitable for studying the impact of installing various features on the behaviour of water in a ship's swimming pool. The objective was to develop a model scale testing tank which emulates current cruise ship pool designs. The model was to be installed on a 6-axis motion shaker which will simulate the motions experienced by the pool when the ship moves in a seaway. The influence of depth changes and installing features along the pool was assessed by evaluating water elevation, number of elevation peaks and overall free-surface behaviour.

Experiment setup

The experiment was conducted at the university's Human Factors Research Unit using a 6-axis motion table. A model testing tank of scale 1:12.5 was custom built out of Perspex, modelled after current cruise ship pool designs. From analysis of pool dimensions on a range of ships, it was found that 2:1 is a typical length to width ratio, with depth varying from 1.5m to 2.3m. Additionally, beach areas around the pool are becoming larger and increasingly popular among guests. These areas aim to create the impression of a larger pool area as well as increasing the space where people can 'contact' the water. Taking this into account, basis pool parameters were defined (Table 1).

The motions, as experienced by the pool onboard a vessel, were defined and used as input to the motion table. To do so, an Atlantic crossing was taken as an area where pool sloshing is plausible. Two sea states were considered: the most common, at head and bow-quartering seas, and a harsher head sea state likely to heavily excite sloshing. The most common sea condition, likely to occur 8% of the time, has a significant wave height of 7-8m and a mean zero crossing period of 2-3s. The harsher sea state has a significant wave height of 10-11m and a mean zero crossing period of 3-4s, being representative of 1.8% of possible sea state encounters.

This data was gathered and equated with a basis ship response amplitude operator (RAO) to generate a response spectrum. The RAO was derived from scale model tests and supplied by a cruise ship operator. The generated response spectrum is

Length	11m
Width	4.9m
Depth	1.4 - 2.25m
Beach area	72m^2
Vertical distance to LCF	44m
Horizontal distance to LCF	21m

Table 1: Full scale basis pool parameters

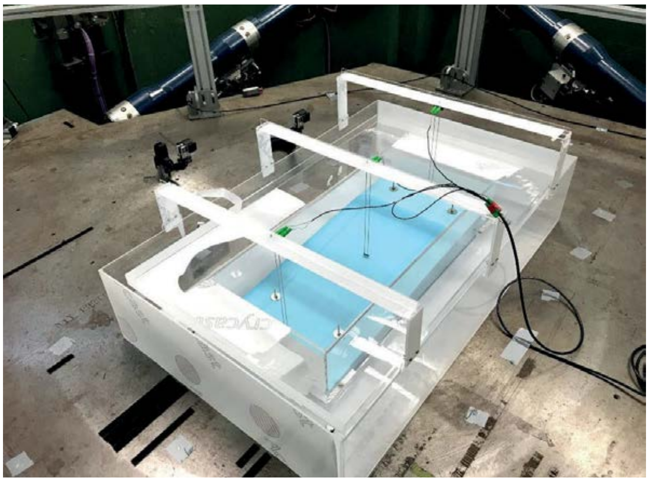


Figure 1: Experimental testing tanks mounted to the 6-axis motion platform

translated to the time domain for each motion axis, scaled and the motions at the pool generated through trigonometry. For instance, pitch motion is split into vertical and forward-aft motion. The latter is greatly responsible for inducing sloshing. The motions for each degree of freedom were fed into the Human Factors Research Unit's 6-axis motion platform where testing was performed (Figure 1).

Sloshing suppression devices

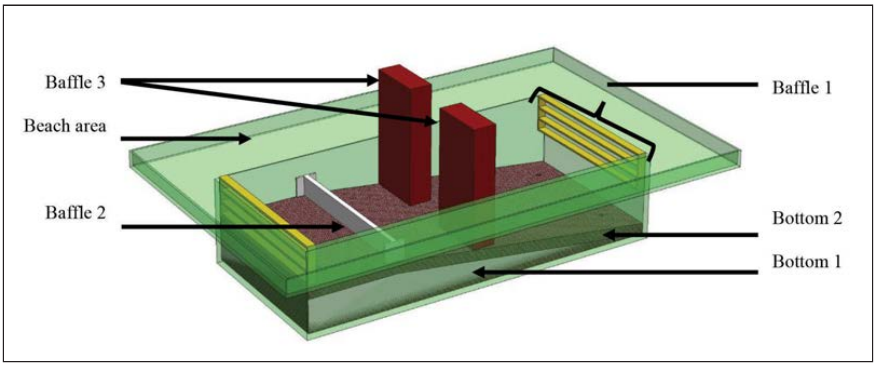
Currently LNG carriers and road tankers employ sloshing suppression devices, referred to as baffles. These are typically vertical or horizontal beams placed on the wall of the tank, aiming to either dissipate wave energy or change the natural frequency of the tank. Three baffle designs were examined in this study, attempting to incorporate the principles adopted in LNG tanks into feasible designs for a swimming pool environment. This means that these had to be safe according to entrapment and drowning regulations [4], as non-intrusive for users as possible and not limit the pool's operability under any condition. Figure 2 shows a 3D CAD model of the testing tank with all baffles and bottoms installed.

The first suppression device, referred to as Baffle 1, was designed as an energy dissipation device. In theory, as the water moves along the pool wall, the vortices generated at the tip of each baffle – due to viscosity – should dissipate energy and reduce sloshing amplitude. The device was designed with the following specification, referring to K. Hyunjong [5], l/L% = 3%, where l is the protrusion width of the baffle. The gap between baffles was dimensioned according to entrapment requirements.

The second sloshing suppression device proposed, referred to as Baffle 2, consists of an underwater vertical barrier. In certain instances, this should alter the natural frequency of the fluid by reducing the pool's effective length. Additionally, flow separation may occur at the edge of the baffle. The ratio H/h% was chosen to be 70%, where H is the depth and h is the height of the baffle.

The third suppression device, referred to as Baffle 3, attempts to realise the benefits of physically dividing the pool whilst tackling its main disadvantage, the reduction of the pool length. To do so, two barriers are installed at either side of the midpoint, leaving enough width for people to swim between each pool end. The barriers have a full-scale width of 1.7m and length of 0.7m.

Figure 2: CAD design of the basis pool with the bottoms and baffles installed



Testing procedure

The free-surface behaviour for each of the three different sea states is analysed for each baffle installed. Each run was 8m30s, corresponding to approximately 30 minutes full-scale motion. Arrangements were tested including the current bottom configuration and a raised bottom with and without baffles. For each new feature installed all sea states were run. Wave amplitudes at three locations along the pool length were measured using resistance probes with a 100Hz acquisition rate. Video was recorded for all runs at two locations. Figure 1 shows the camera setup, wave probes and the bottom profile installed.

Results

Figure 3 presents the averaged results across the three sea states. Overall, the introduction of a raised bottom to reduce pool depth (referred to as Bottom 2) increases the pool's sloshing response slightly. From this data it is obvious that all baffles resulted in some kind of improvement to the free surface behaviour when compared to the Bottom 2 condition. As predicted, the sea state with higher wave amplitudes showed greater responses. Moreover, for the same sea state, the bow quartering heading resulted in incrementally greater responses.

Baffle 1 resulted in reductions in the average peak amplitude of 5% to 7%, depending on the sea state, specifically at the middle of the pool. These, however, are not enough to significantly counteract the increases created by the raised bottom. Nonetheless, the maximum peak amplitude and peak number are reduced for all sea states.

The installation of Baffle 2 resulted in an overall reduction of all measured parameters to a greater extent and more consistently than seen with Baffle 1. There is a 40-55% reduction in the mean peak amplitude, 25%

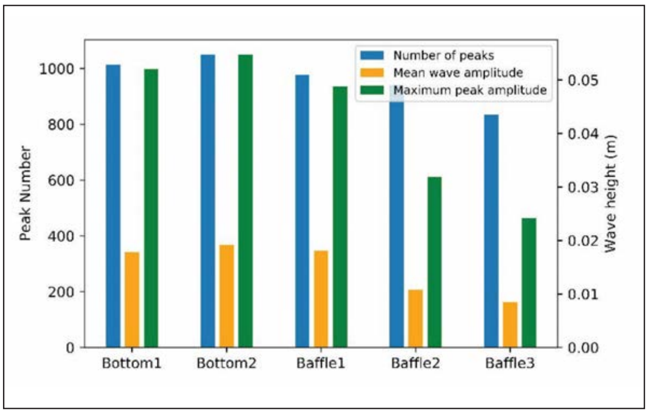


Figure 3: Averaged results across the three sea states for number of peaks, mean wave amplitude and maximum peak amplitude

to 60% reduction in the maximum peak amplitude and 35- 60% decrease in standard deviation. The implementation of such a baffle, in a shallower pool, would improve the free surface behaviour compared to the current bottom, as may be seen in Figure 4. The working principles of this suppression device are simultaneously the reason for its success and its operational and safety drawback. The vortices generated at its tip dissipate energy to a great extent. However, these vortices can create significant downward forces, potentially causing users to be pulled toward the pool bottom.

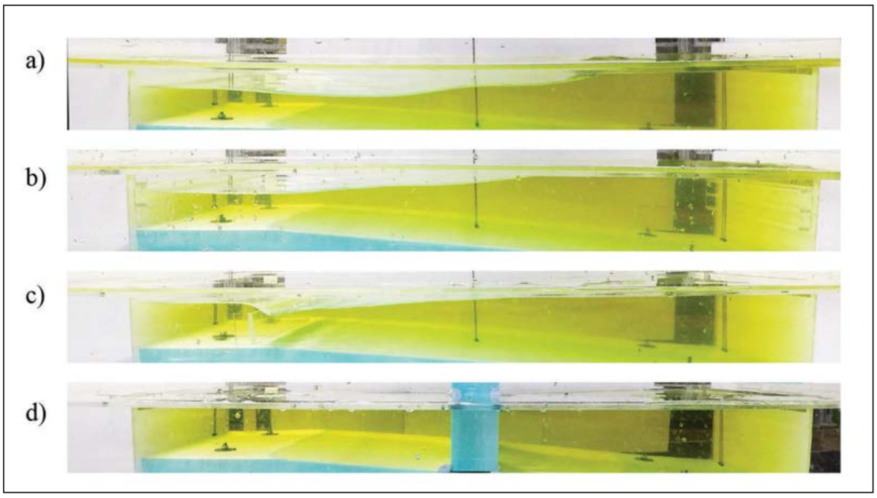
Baffle 3 performed the best for all parameters measured. Mean peak amplitudes are reduced by 45-70% depending on the sea state compare to the Bottom 2 configuration. Similar reductions are observed for the maximum peak amplitude. A much smoother surface profile is achieved (Figure 4). Unlike Baffles 1 and 2, Baffle 3 appears to be equally effective in both the harsher sea state and for bow-quartering seas. The outstanding performance of this baffle is due to the fact that its effects are not local to the device, as with the other baffles.

Conclusion

A model-scale swimming pool experiment was developed to assess the responses of pool water in irregular sea conditions. The model-scale swimming pool was fixed to a large 6-axis motion platform in order that measurements of water motion in the pool with it undergoing representative vessel motions may be made.

In general, a decreased pool depth results in increased pool sloshing responses. However, this study shows that it is possible to have shallower swimming pool depths onboard cruise vessels if baffle systems are employed. Passive suppression devices either change the natural frequency of the system, therefore changing the pool's response to a given sea state, or dissipate the energy associated with the pool's water motion. Baffles that change the natural frequency of the water in the pool are seen to perform better. A partial separation of the pool into two halves decreases the average, maximum and standard deviation of measured wave amplitudes. The number of peak wave amplitudes measured is also decreased in the sea states evaluated. Furthermore, it is believed that such baffle arrangements could be easily incorporated as an aesthetic feature of the pool.

Figure 4: Free surface profile at the same instant under a sea state with significant wave height of 7-8m and a mean zero crossing period of 2-3s. a) Bottom 2 b) Baffle 1 c) Baffle 2 d) Baffle 3



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About the authors

Diogo Nunes is a student in Ship Science with Naval Architecture in the Faculty of Engineering and Physical Sciences at the University of Southampton, UK.

Dominic Hudson is the Shell Professor of Ship Safety and Efficiency at the University of Southampton. He has research interests in all aspects of ship hydrodynamics, performance management and operational efficiency. He is a Chartered Engineer and member of RINA. He is presently a member of the 29th ITTC Specialist Committee on Ships in Operation at Sea and the RINA IMO Committee. *NA*

Sailing to the beat of a different drummer

Propeller noise is a rapidly expanding area of research, but what are the underlying principles? HydroComp's Don MacPherson gives a primer

Late November is a cold time in Halifax, Nova Scotia, but for two days last year it was the hotspot for a gathering of marine professionals, ship operators, academics, and representatives from government and other regulatory agencies to discuss ship noise mitigation. Hosted by CISMaRT (www.cismart.ca) and supported by Transport Canada, the workshop provided a setting for training, discussion, and collaboration. As a participant at the event, I found it to be an outstanding overview of the state-of-the-art in many aspects of Underwater Radiated Noise (URN), yet there were also a few things that surprised me.

While all seemed to appreciate and accept that propellers are the dominant source of detrimental ship-generated radiated noise, it became clear that the mechanism of propeller-driven noise is not well understood at all. I hope to use this article to offer a 'practical primer' on this topic. (I also am intentionally avoiding any discussion about the social and environmental impact of noise. There are others much more qualified to speak about this). Let me acknowledge that I am not an acoustic expert, just a practitioner (albeit one with a special interest in the topic and experience in hydrodynamic systems) that is driven to peak behind the curtain.

Three-part harmony

SLAM! Now it's your turn. Take your hand and slap your desk. Why you hear any noise at all is the result of a three-part system of Excitation, Transmission, and Response.

- Excitation is the source of the noise, such as your hand slapping the desk.
- Transmission is the highway for the energy that propagates from the source. In this case, air provides the fluid pathway, but the medium for transmission could be gas, liquid, or solid as long as it has some elasticity.
- Response is how your body accepts and responds to the energy from the transmission fluid. The eardrum picks up the fluid motions and converts it into signals that your brain processes.

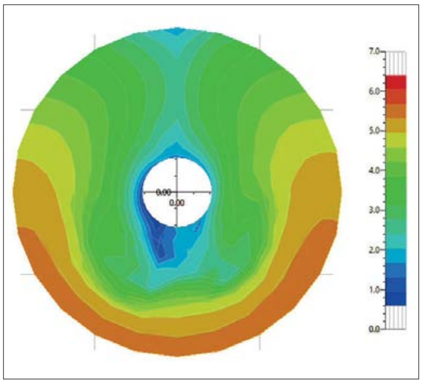


Figure 1: Propeller wake field. Boundary layer thickness will increase with distance from the bow

Every such system is unique, but they all more-or-less follow a similar framework. Let's first distinguish between sound and noise. Sound is the term for the physical process, the conversion of source energy into a response. Noise is simply disruptive or unwanted sound, and admittedly, this can be a very subjective term (as a bagpiper, I am frequently reminded of the distinction).

Now in professor-speak: *Sound is a vibratory mass fluctuation that travels through an elastic medium.*

But wait, I just slapped my desk once? How is this vibratory? Even though the sound is processed as a single "burst" it is in fact made up of a spectrum of vibratory subsets at very tiny time scale. The energy from your single impact caused the spring-damper system that is your desk to vibrate and reflect the fluid back to you. The nature of this sound depends not just on the impact energy, but on the physical characteristics of the impact site. Not quite sure? Slap a pillow. While there is indeed a whisper of noise from the mass being moved by your hand, it is a fraction of the sound energy that was reflected by the desk – and at a differing frequency as well.

OK, now set off a firecracker on your desk. Just kidding! Don't try this at home. But it does provide an illustration of a different kind of sound generation – the direct mass fluctuation of the fluid via an explosive expansion or contraction within a very, very small time frame. The thunder created by a lightning's instantaneous heating of air is another such example.

Propeller-driven noise

This sets the stage for a deeper understanding of propeller-driven noise. There are two noise sources in play here – non-cavitating and cavitating – and they are similar to the two described above.

Frequency of noise

Propeller-driven noise sources most significantly occur at each blade's passing though a region of slower water – hence the name 'blade rate' or 'blade pass' frequency (BPF). The BPF is the principal frequency of noise generation, with its first two or three multiples as additional significant frequencies.

As a propeller blade rotates through its circumferential path, it passes incoming water travelling at different velocities – its 'wake field'. Figures 1 and 2 show examples of differing water velocities and how boundary layers on hull and appendages can create this non-uniform inflow. Oblique flow due to shaft angle can also be a major contributor to variation in the wake field.

Frequency is an important consideration in the 'radiated' part of URN, as lower frequency pressure wave systems can travel much farther than those at higher frequencies. This means that the region of potential acoustic 'damage' is much farther away from the source. There is also some speculation that a perceived regular sound is more psychologically harmful than a collection of higher-frequency 'white noise'. Consider rain. I find it soothing but a continuous single... regular... drip... on a metal lid can drive you crazy.

Non-cavitating noise

This temporary passing from higher velocity to lower and back again is akin to a wing traveling with a fluctuating angle of attack. This brief increase in lift and thrust (also called a 'gust') imparts a periodic load on the blade and is often referred to as a 'pressure pulse'. Just for reference, the time of a blade passing a slower region on a merchant ship (e.g., the sweep through the darker green region in the wake field plot above) is just a few hundredths of a second.

While the pulse itself can alter flow enough to cause direct noise, it is the vibratory noise that is the principal source. Like your desk top, the propeller blade is a spring-damper system that is responsible for reflecting imparted energy. The shape and typical metallic material properties of commercial propellers cause them to be effective vibratory reflectors.

Non-cavitating noise is one of a soup of noises generated at lower ship speeds. Machinery and hull noise actually can be the principal sources of ship noise at these lower speeds, with non-cavitating propeller noise as a lesser contributor. Once a propeller cavitates, however, everything changes.

Cavitating noise

Cavitation is the dominant noise source associated with harmful URN, as mass fluctuation is caused directly by the instantaneous expansion and collapse of what can be sizeable cavitation volumes. Cavitation comes in different types, and not all types are important noise producers. For example, cavitation that remains as individual bubbles will collapse in a chaotic fashion, resulting in a band of noise often sounding like a can of pebbles (typically between 1,000 and 2,500Hz).

Sheet and tip vortex cavitation, on the other hand, produce strong singular cavities of substantial volume. These are created and destroyed during each blade pass, and are the source of high energy spikes in the noise spectrum at BPF (and multiple) frequencies.

Tip vortex cavitation has the distinction of typically being the first cavitation encountered as loading is increased on a propeller (by an increase in speed or towpull). It therefore can be a useful metric for defining the critical point of cavitation inception. (You may see this referred to as a Cavitation Inception Speed or CIS.)

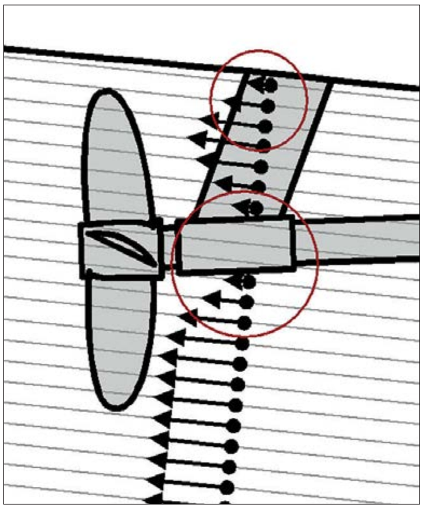


Figure 2: The propeller shaft angle creates oblique flow, which influences the wake field

In simple terms, a tip vortex is created by fluid movement across the blade tip due to the differential between the pressure and suction sides of the propeller. (We have all seen the tip vortex from an airplane wing – same phenomenon.) When the vortex is strong enough, its internal pressures drop and a cavitation tube is formed. It is a significant explosive fluctuation noise-producer when the cavitation tube collapses in the trailing wake. For ships with a mission requirement for low-noise operation, such as a research vessel, it is important for designers to avoid or delay tip vortex cavitation.

Noise mitigation

There are a variety of design strategies for the mitigation of propeller-driven noise and they generally focus on two objectives: improving the inflow uniformity and reducing blade pressures.

Inflow uniformity

To improve noise, think like the water. Reducing the variation in the wake field velocities will reduce the strength of the periodic loading and unloading pulses on the blade. And remember, the big noise problems come from the rapid and strong generation and collapse of the cavities, also due to variation of the inflow.

Improving the inflow is always justified. Noise is not just about the propeller, but about its interaction with the environment in which the propeller works. It is important to remember that uniformity is critical around the rotational circumference but not so much in the radial direction. In other words, any particular radius on the blade should "fly" through water with as little variation as possible, but it is OK to have different velocities at different radii. The characteristics of each radial blade sections (e.g., chord, pitch, and camber) can be adapted to its axial and tangential inflow (hence the term "wake-adapted" design).

Reducing blade pressure

The propeller thrust needed for a particular speed is constant, so mitigation of noise requires compromise via altering or shifting thrust development on the blade. These include the following:

- Unloading the blade tip via reduction in blade pitch or camber. This will shift the loading lower in the span of the blade to reduce the pressure differential near the tip. Of course a strong differential is necessary for thrust-making, so carrying parts of a blade that are not fully developing thrust comes at the cost of lost propeller efficiency. It is important, however, to be careful about increasing the loading too much at lower radii, as this can create a strengthening of a leading-edge vortex that rolls up into the tip. This is particularly important for highly-skewed propellers, and it suggests incorporating the next item in our list.
- Reduce the pressure differential with a wider blade – even at the tip. Pressures are reduced as the required thrust is distributed over a wider area. Again, the added drag of a wider blade surface for the same thrust contribution reduces efficiency.
- Increase blade count. For propellers where complete unloading is not possible (which would be most propellers for commercial applications), it can be beneficial to distribute the thrust over a greater number of blades. This will generally not eliminate the tip vortex but will reduce the strength of each individual vortex. Similarly, other cavity volumes can be smaller per blade. Less amplitude at higher frequencies.
- A larger or smaller diameter – which is best? Well, it depends. While you can reduce blade pressures with the

greater area of a larger diameter, this will reduce the transmission distance (the tip clearance). That being said, it is important to appreciate that the useful rules-of-thumb for tip clearance generally do not consider the other measures that might have been taken. So, if you are unloading the tip, you might be able to increase diameter.

Why are propellers still producing noise?

Great question. This was the other thing that struck me at the meeting – how the analytical predictions for propeller noise sources are offloaded to propeller specialists. Let me note two particular items raised during the meeting:

- System noise models are generally of a type called "Statistical Energy Analysis" (SEA), however, for these codes, the propeller excitations are not calculated but added as a separate external noise source. Where these sources are supposed to come from is uncertain.
- URN mitigation is still a selective task, not yet mandated or a company priority (for most). I am not being critical, just realistic. The cost of fuel and impending emissions regulations are going to be at the top of the list.

Of course, this means that comprehensive noise mitigation will also require simultaneous evaluation of the cost of doing so, in terms both of capital cost as well as operational cost. Short of model testing (with uncertain expansion to full scale) or complex numerical codes, there is currently no practical way for the assessment of propeller-driven noise production without the consultation of a subject matter expert. Ship designers need the ability to evaluate fundamental URN metrics early and in a way that is also integrated with hull form and propulsion system design decisions.

So what is HydroComp doing about it? I am pleased to be a contributor to HydroComp's maritime sustainability initiative (http://hydrocompinc.com/blog/sustainability). Every new product development decision includes a check of what it can contribute to noise mitigation, fuel conservation, or the reduction of GHGs. Propeller blade design for noise reduction is currently part of the work of many in our PropElements software user community.

Closer to home, work is being undertaken in-house to develop parametric prediction models for the influence of blade tip parameters on radial loading for the NavCad hydrodynamic and propulsion system simulation tool. Couple these with new models for noise source prediction and propagation, and we are encouraged that meaningful noise mitigation for practicing naval architects is quietly approaching. *NA*

A practical method for propeller noise

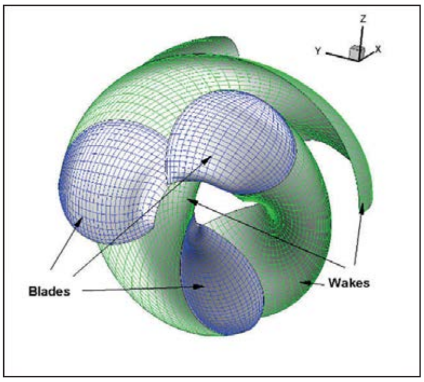
Ahmet Soydan and Sakir Bal of Istanbul Technical University set out numerical formulae by which propeller radiated noise may be investigated

Traditionally, only the engineers and designers of submarines, naval, fishing and research vessels have had a significance interest in underwater radiated noise. In recent years, however, underwater noise has become a growing concern throughout the entire maritime industry.

Sources of underwater radiated noise on a marine vessel can be divided into three main categories: engine noise, flow noise and propeller noise [1]. To reduce the engine noise, isolation equipment can be installed or the engine foundation may be resiliently mounted instead of rigidly mounted. Ship hull form should also be designed to decrease the hydrodynamic noise. But it is the propeller that is the dominant noise source on marine vessels.

Propeller noise is important for detection of vessel location and velocity, but also impacts the comfort of passengers and the environment. Due to these reasons, hydrodynamic properties and acoustic performance should be taken into consideration when designing propellers. Therefore, an accurate calculation of the noise due to marine propellers is an important subject within the maritime industry. The designer should consider that the propeller must satisfy the desired thrust and torque values, while minimising the radiated noise in the concept design stage.

Previous research, conducted in 1996, into quantifying propeller noise inboard a twin screw passenger vessel took a practical approach [2]. Full scale experiments were conducted on 15 cruise liners and ferries. According to this study, noise caused by tip vortices can be estimated by tip vortex index (TVI) technique. Later this TVI technique, coupling an empirical formula with a lifting surface method, was applied for the prediction of the inboard noise level of a three-bladed DTMB 4119 model propeller [3]. Two and three-bladed model propellers were investigated for the hydro-acoustic performance operating under cavitating and non-cavitating conditions. But for this study a very practical and simple method, based on the semi-empirical Brown formula, is described for non-cavitating marine propellers. The method can also be extended to include the cavitation effects in calculations. However, for simplicity those effects have not been included in this article.



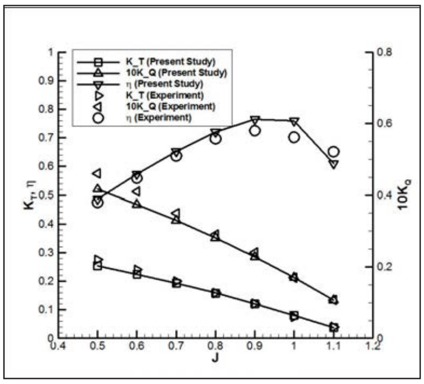


Figure 1. (above) Perspective view of DTMB 4119 propellers and its wakes

Figure 2. (below) Comparison of thrust, torque and efficiency of DTMB 4119 propeller (Z = 3).

Hydrodynamic validation

First, the hydrodynamic parameters and the flow around the model propeller have been solved by the lifting surface method developed before [4]. The lifting surface method models the three-dimensional steady flow around a propeller by representing the blade and wake as a discrete set of vortices and sources, which are conveniently located on the blade mean camber surface and wake surface. The kinematic boundary condition must be satisfied at certain control points located on the blade mean camber surface. It requires the flow to be only tangential to the surface. The details of the method can be found in [4].

The benchmark model propeller has been selected as DTMB 4119. The model propeller has three blades and no skew or rake. The diameter of propeller is D = 0.3048m. Design advance coefficient is J = 0.833. Main particulars and other geometric details of the propeller are given in [4]. The panel distributions on DTMB 4119 model propeller (Z = three-bladed) are shown in Figure 1. The wakes behind the propellers have also been modeled. Corrections for scale effect (Reynolds Number corrections) have been made by the method of Wageningen [1]. Lifting surface method has been validated with the available experimental data (in terms of thrust and torque coefficients and efficiency values) of three-bladed propeller under non-cavitating condition.

The results by the present lifting surface method have been compared with experiments as given in Figure 2. It is very clear that the agreement between present lifting surface method and experiments is satisfactory.

Hydroacoustic validation and discussion

Later, the semi-empirical Brown formula, which is based on broadband noise estimation, was applied for the noise spectrum [5, 6]. This approach is used to calculate the total sound pressure level (SPL) at a reference distance (1 metre) in Z direction.

$$\mathrm{SPL} = 105 + 10log\left(\frac{ZD^4n^3}{f^2}\right) \qquad (1)$$

Here, Z is the blade number, D is the propeller diameter (metres) and n is the propeller rotation speed (rps) while f is the noise frequency (Hz). *SPL* represents the noise level in dB. The coefficient on the right hand side of above equation (Equation 1) is found as 105dB after the validation study of selected DTMB 4119 propeller with those of another study [7] as shown in Figure 3. SPL can also be given as (by definition),

$$SPL = 10log\left(\frac{p}{p_{ref}}\right)^2 \qquad (2)$$

where p is acoustic pressure (Pa) and p_{ref} is reference acoustic pressure (for water p_{ref} = 10-6 Pa). Overall sound pressure level (OASPL) can then be computed by,

$$OASPL = 10log\left(\frac{p_{rss}}{p_{ref}}\right)^2 \qquad (3)$$

Here, p_{rss} is the root sum square of pressure [8]. Computed OASPL values including thrust and torque values under different working conditions are shown in Table 1. Advance coefficient, $J=V/(nD)$ is taken as constant and equal to 0.833 for all cases here.

Now let us assume that OASPL can be given as,

$$OASPL = 10log\,(n^a\,V^b\,T^c\,Q^d) \qquad (4)$$

a, b, c and d powers can be calculated by using the values given in Table 1. As shown in the last column of Table 1, this simple and practical approach gives satisfactorily good results. Note that OASPL values can also be assumed as a function of diameter, number of blades, blade area ratio, pitch values, etc.

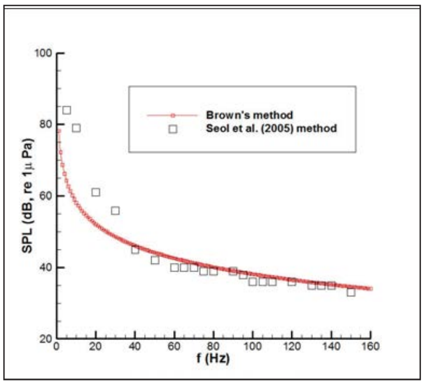


Figure 3. Comparison of SPL by Brown's formula and those of Seal *et al.* (2005) (7)

Conclusion

Propeller radiated noise has been investigated by a practical numerical method. The sound pressure level has been calculated with Brown's formula. A lifting surface method with scale (Reynolds Number) corrections applied for hydrodynamic analysis. OASPL values have then been computed by a practical and simple formula given in Equation 4. Mainly, it has been found that OASPL values can be assumed as a logaritmic function of rotational speed, advance velocity, thrust and torque values of a propeller.

A propeller working with a rotational speed and an advance velocity will generate certain thrust and torque values. By using Equations 1-3, OASPL values can be calculated at four different working conditions as shown in Table 1. With the help of these OASPL values, a, b, c and d powers in Equation 4 can easily be found for a certain propeller. Once a, b, c and d powers in Equation 4 for a specific propeller are known, one can easily get the OASPL values at other working conditions. Since there is no information particularly on advance velocity in Equation 1, Equation 4 can be considered as an improved approach. Designers can use it to comprehend which factor is dominant for OASPL. Other parameters such as diameter, number of blades, pitch ratio, rake, skew, etc., can also be included into Equation 4. *NA*

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About the Authors

Ahmet Soydan is a graduate student and Sakir Bal is a professor from Istanbul Technical University, Department of Naval Architecture and Marine Engineering.

Table 1. Relationship between velocity, rotational speed and OASPL values

n (rps)	*V* (m/s)	Reynolds Number	*T* (Thrust) (N)	*Q* (Torque) (N.m)	Kt	10*Kq	OASPL (Eqn. 3) (dB)	OASPL (Eqn. 4) (dB)
6,667	1,693	1225014	56,3516	3,0899	0,1472	0,2647	96,5	96,3
10	2,539	1837428	127,6787	6,9515	0,1482	0,2647	107,1	107,0
15	3,808	2756143	287,6727	15,6784	0,1484	0,2654	117,6	117,4
40	10,156	7349714	2079,3000	112,6200	0,1508	0,2680	143,2	143,1

Austal's smart ship journey

The evolution of the HSC manufacturer's unique smart system has been built on a reappraisal of design priorities and Big Data-powered optimisation, writes Max van Someren

For the past two years, the world's largest builder of high-speed craft (HSC), Austal, has been developing its own take on the smart ship concept. At the heart of Austal's vision is Marinelink-Smart, a crew advisory system now embedded in every new Austal commercial ship. The system is tailored to the unique requirements of HSCs. It builds on Austal's 30 years of experience in the industry as well as collaborations with sensor manufacturers, cloud-computing providers and academia. The goal is to enable HSC crews to achieve optimal fuel efficiency and passenger comfort on every journey, all year round.

Founded in Western Australia in 1988, Austal has built a global reputation for fuel efficient and comfortable high speed ships on the back of continual innovation. Launching its smart ship initiative in late 2016, Austal sought to apply the company's HSC design know-how and operations experience in the digital era.

Figure 1. *Benchijigua Express*: the world's largest high-speed craft and the first example of Austal's innovative stabilised monohull hullform

Design thinking

To explore the potential benefits smart ship technology had to offer Austal's customers, the company's technology development department went back to the drawing board. They asked themselves: *What are the underlying forms of customer value that would differentiate the next generation of Austal designed smart HSC in the market?*

To address this question the company worked with Curtin University, also based in Western Australia, in a week long design thinking 'sprint'. Experts from Austal and Curtin University met with HSC crew members to develop an in-depth understanding of the needs of HSC operators. The team then developed realistic software prototypes which were tested with customers at the end of the sprint week.

The sprint process confirmed some existing assumptions and revealed new insights. For example, while fuel is a HSC operator's greatest expense, it became clear that the relative importance of fuel efficiency versus passenger comfort varied greatly between operators. The team concluded the trade-off between the two would need to be a configurable feature of the system.

Partnering with academia

The design thinking workshops enabled Austal to plan out the features which would save HSC operators fuel and improve passenger comfort. This included: trim, throttle and ride control optimisation; route and heading advice based on live environmental data; and fuel-consumption and passenger comfort benchmarking.

The team reviewed the smart ship market and met with several providers of smart ship systems. However, it quickly became evident that these systems, designed for general purpose application in the broader maritime market, were not suitable "off the shelf" to meet the performance characteristics and requirements of HSC.

With the decision made to build its own system, Austal chose to collaborate with

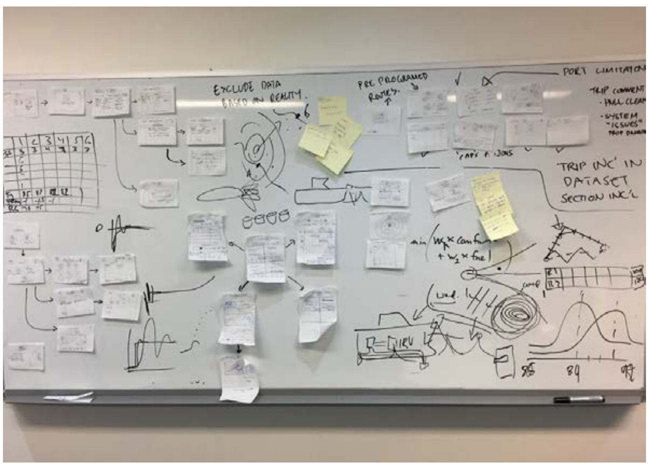


Figure 2. Austal employed design thinking techniques to better understand how their customers would use a smart ship system

another university to harness the latest developments in Internet of Things (IoT), machine learning and Big Data across other industry sectors and apply these to the development of Marinelink-Smart. Austal decided to base its Marinelink-Smart development team on-campus at the University of Western Australia to maximise interactions with leading academics and graduate students.

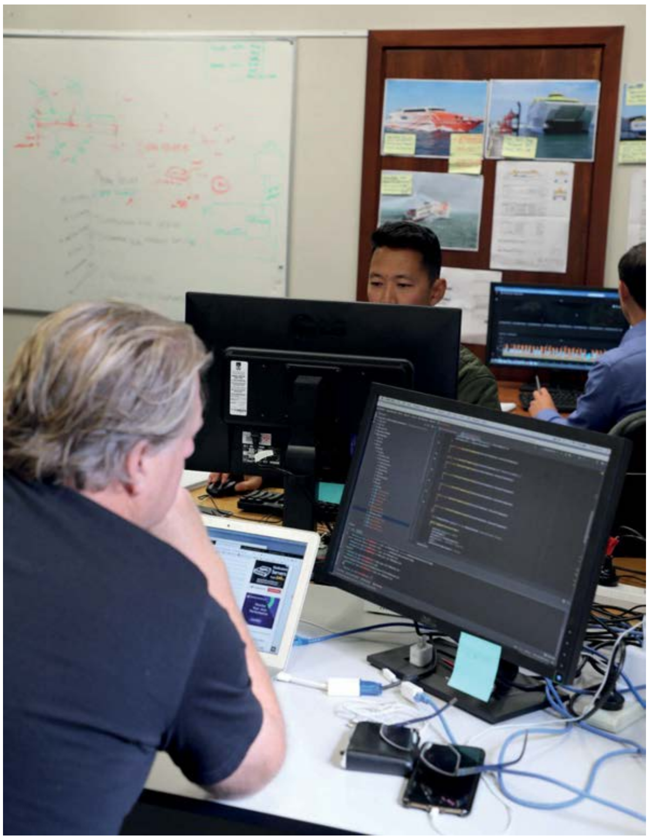


Figure 3. Austal are developing Marinelink-Smart in close partnership with the University of Western Australia

Designing from the keel up

Austal is unique amongst HSC builders in offering its own monitoring and control solution, Marinelink, which is tightly integrated into the design of the vessel. This system has been in-service on almost every Austal-built vessel delivered in the last 20 years. Tight integration with the ship design enables the crew to control the vast majority of the ship's systems from one integrated bridge console.

The same design philosophy has been applied to Marinelink-Smart. Advice is provided directly to the crew via a simple to use tablet interface on the bridge. In the background, data on the ship's performance and operating environment is continuously streamed to Austal's secure cloud data repository. Here, the data is used to update the algorithms that provide the live advice, which is synchronised with the ship regularly. The data is also available for viewing and export by the shore-side customer team.

Since early 2018, the system has been installed on four HSCs and data from several thousand individual voyages have been logged, operating in a range of environments globally. Two 117m trimaran vessels are currently under construction by Austal for Fred Olsen SA and will be the first to have Marinelink-Smart built in from launch. This includes an Ethernet-based smart sensor network to enable fast and easy connection of new IoT devices over the life of the ship. This is just one example of the benefits if smart ship features are integrated in to the ship design from the outset.

Fuel savings and comfort improvements

Over the last year, Austal has gathered considerable information on the potential improvements to fuel efficiency and passenger comfort, which live advice from the Marinelink-Smart algorithms can provide. For example, altering the angle of the ship's trim tabs to adjust the dynamic trim can improve fuel consumption by up to 3%. In another case study, Austal identified that correct ballasting to achieve optimal static trim could result in fuel savings of up to 5% on any given day. This translated to an average fuel saving of 1.5% over six months when compared to existing ballasting practices. While 1.5% may be modest, Austal anticipates the aggregation of recommendations from subtle 'tweaks' to the ships operations, in real-time, will become significant. The

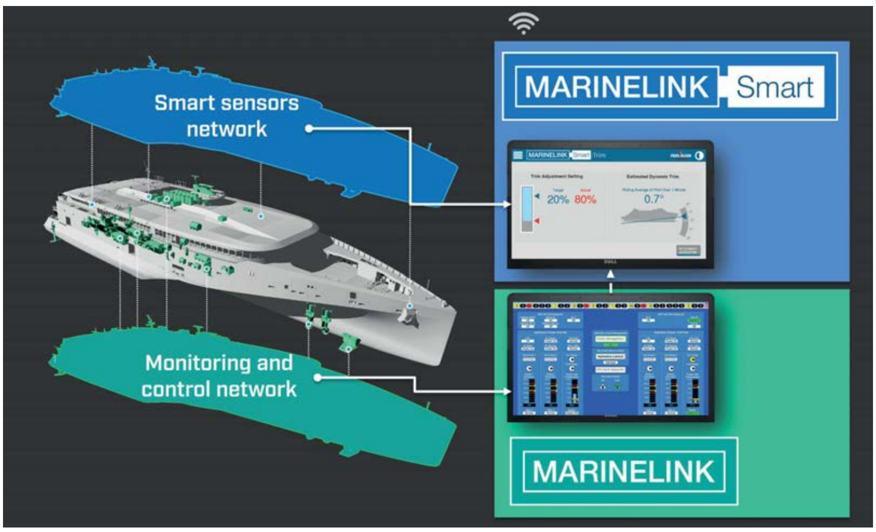


Figure 4. Marinelink-Smart draws data from the ship's existing on-board monitoring and control system as well as additional environmental and other sensors

company views the claims of other smart ship system providers of up to 10% overall fuel savings as being achievable for HSC, a savings which equates to over US$1 million annually for larger HSC.

An evaluation of Marinelink-Smart's passenger comfort and weather routing features is currently in progress, utilising the streaming data from three HSCs which already have the system installed. Austal hopes to be able to quantify the benefits associated with these features for its customers later this year.

Fig. 6 Marinelink-Smart offers HSC customers a range of onboard advice modules to save fuel and improve passenger comfort

Long-term investment

What is the future for Austal's smart ship journey? The company has invested heavily in the development of the system to-date and shows no signs of slowing down. On the roadmap for this year is the extension of the system in to equipment condition monitoring. Austal sees an opportunity to provide a highly integrated view of equipment health via the Marinelink-Smart system, incorporating not just the data from major equipment itself but a range of other operational and environmental data that may have an impact on overall performance and reliability. The company will continue building partnerships with suppliers, commercial customers and academia to achieve this.

There are also several other features using the latest machine learning techniques which are in earlier stage development and still under wraps. Ultimately, Austal expects Marinelink-Smart to provide the foundation for the integration of a wide variety of other technologies into their vessels. This includes alternative fuels, electrification and autonomous systems, all of which the company anticipates will have a significant impact on the sustainability, efficiency and comfort of HSC into the future. *NA*

About the author

Max van Someren is Technology Development Manager at Austal.

Waterborne platooning by smart vessels for smart shipping

Semi-automated vessel train configurations of inland and short sea could bring considerable efficiency benefits, research conducted by Delft University of Technology has found

Authors

Ali Haseltalab, **Linying Chen**, **Alina Colling**, **Luke Borst**, **Vittorio Garofano**, **Robert Hekkenberg**, and **Rudy R. Negenborn**
Department of Maritime and Transport Technology, Delft University of Technology, Delft, the Netherlands

Economic development is currently putting an enormous pressure on transport systems. The demand for freight transport is likely to grow over the next few decades [1]. If roads and railways are the major means of transport to handle the growth, they will face frequent congestion. In densely populated regions, like cities, road networks are already confronted with congestion and capacity problems.

Meanwhile, inland waterways still have plenty of capacity to transport more goods [2, 3]. Waterborne transport could offer an environment-friendly alternative in terms of both energy consumption and noise emissions [4]. To meet the transportation demand and maintain sustainable development, promoting waterborne transport has gained increasing attention.

Like many other technology domains, there is a shift taking place in the maritime industry towards the adoption of smart technologies for transport over water. In this regard, one of the main objectives is to use the current infrastructure in a more efficient way to handle the ever-increasing problems with congestion, delivery delay, emissions, and transport costs.

Advanced technologies are being applied from different aspects to different domains of shipping. While novel cooperative approaches are being used for solving real-time logistics challenges [17,19], the power and propulsion system (PPS) of ships face revolutionary improvements as fully electric and hybrid PPS configurations are being implemented to reduce emissions and increase fuel efficiency [12—16].

Recently, researchers have started investigating the possibility and efficiency of moving vessels in formation, inspired by similar works in robotics and vehicular technology domains, to increase the efficiency of transport with ships. With regard to inland waterways and port areas, platooning, in which multiple vessels follow each other with a certain distance and form a vessel train, has been conceived as the most suitable formation.

This potential futuristic business case can lead to reduced crew and operational cost, improved accessibility of urban areas, and increased logistics flexibility. As a result, more effective transportation over water can be achieved. Smart ships with advanced PPS can even further increase the efficiency and flexibility of vessel platoons if they adopt novel methodologies for forming and controlling the platoons.

In this article, after elaborating on the advantages and disadvantages of platooning over water from the business point of view, it is explained how novel control approaches combined with advanced PPSes can lead to highly effective, flexible, and fuel-efficient vessel platoons. Furthermore, optimal placement of vessels in a train formation is discussed, which can lead to increased fuel efficiency and minimised water resistance.

The contents of this article are based on the results of research carried out at the Department of Maritime and Transport Technology of Delft University of Technology in the Netherlands. The article provides insight and solutions towards enabling a revolutionary transportation scheme that can address the interests of different transportation parties.

Platooning: pros and cons

Waterborne platooning can be achieved without the need for fully autonomous vessels. In one of the operating modes, which is known as leader-follower, it is sufficient for the follower vessels (FVs) to be equipped with technology that allows them to track the platoon leader and keep a safe distance to the vessel in front of them. Such a transport solution is currently being investigated by the NOVIMAR project [5], in which it is assumed that the leader vessel (LV) is fully manned and in charge of navigation of all FVs whilst they are in the train.

The automation of the navigational tasks on the FVs is expected to bring them an economic benefit by reducing the operating costs and thereby improving the competitiveness of waterborne transportation. The way in which these cost savings are achieved differ depending on the sector the platoon operates: In the sea going sector, up to 42% of the vessels' operating cost comes from crewing [6]. The automation of navigational tasks thus requires less crew members onboard for the same operational activities and it has been shown that up to three crew members can be taken off board by automation of the navigational tasks alone [7].

For the inland sector, advantages are expected to be gained in a different manner. Inland vessels have smaller crew sizes than short sea vessels. Their crew size ranges between two and five members [8] yet crewing for smaller inland vessels makes up 56% of the vessels fixed cost [9].

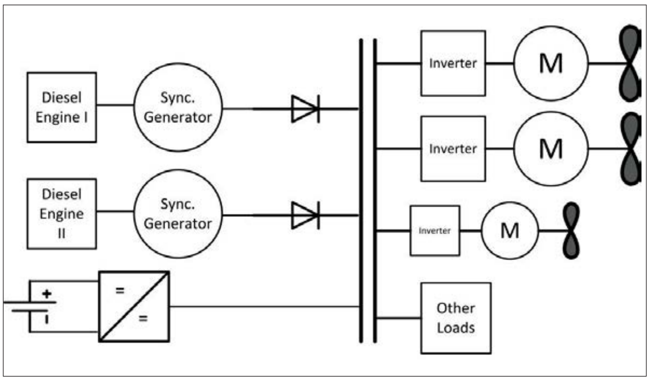


Figure 1: An all-electric architecture with diesel-generators and a battery as energy sources

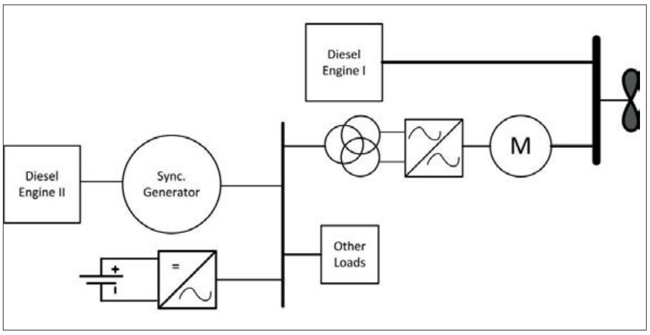


Figure 2: A hybrid architecture with diesel engines and a battery

Inland vessels follow sailing regimes of 14, 18 or 24 hours, which determines the minimum crew requirement onboard. Vessels that currently operate at 24h sailing regimes could make use of the vessel train to keep operating on a 24h schedule but with the crew of an 18h regime. Simultaneously, vessels with smaller crews, operating at 14h sailing regimes, may be able to keep their crew as is but sail on a 24h regime. They would be making use of resting time for their crew and the take-over of navigational responsibility by the leader vessel to raise the productivity of the vessel.

The enhancement in operating time of the platoon provides a further increase relevant for the inland sector if the European Commission starts to keep a closer eye on the exact shift time each crew member spends working, as they do in the trucking industry with the tachograph [10].

Enhancing the level of technology on vessels can take a great amount of convincing and time for ship owners, since enabling waterborne platooning requires large investments and a culture change in the traditional maritime sector. Technological enhancement of full automation also faces liability challenges similarly to other industries. Platooning with crewed vessels can thus be seen as a stepping stone to enhance the automation level onboard without having to deal with several challenges of autonomy.

Providing platooning services creates some business case difficulties. Aspects such as waiting times at gathering places of vessel trains or at bridge/lock passages can cause increases in the trip time. Such waiting times will decrease the benefits the FVs can make within the train. A possible manner to minimise such waiting times could be to create platooning services that operate with high departure frequencies.

Furthermore, the interaction between locks/bridges and the platoon operators can be optimised. This however could only be done on routes with large cargo flows and would require a large number of LVs. The LV services in turn can also be provided in different business models that will affect the economics of the entire vessel train. A dedicated LV will allow greater flexibility in destination but will be more expensive as a service, whilst a multipurpose cargo vessel with the capabilities to lead a train will be cheaper concerning contribution costs but more restricted in its departure and destination [11].

As can be seen from these few examples, the development of an economically viable business model for waterborne platooning involves finding the balance between many different aspects and challenges. Operating in a vessel train does, however, hold the potential to become a solution towards a modernisation in the shipping industry.

To enable waterborne platooning and turn it into an advantageous transport scheme for different waterborne transportation sectors, several technological challenges should be addressed. These challenges range from control and artificial intelligence challenges to design and efficiency issues. In the remainder of this article, several solutions for some of these challenges are discussed.

In the following, it is also explained that platooning can be a quite flexible transport approach in which all the vessels can decide on the vessel train specifications (such as speed and number of operating vessels) and does not only happen under the leader-follower protocol, where the leader decides on all the features of the vessel train. This makes platooning a fruitful waterborne transport scheme for all the parties involved.

In the next section, the role of innovative power and propulsion system architectures for having fuel-efficient vessel trains is discussed.

Advanced power and propulsion system configurations

Alongside increased autonomy, and mainly due to environmental restrictions from international maritime authorities, there is a shift towards more efficient Power and Propulsion System (PPS) architectures as a replacement for direct-diesel propulsion configurations. Based on the agreements made in the International Maritime Organization (IMO), the shipping industry agreed to reduce its carbon emissions by 50% from 2008 levels by 2050. To address this, alternative energy sources are combined with innovative – and mainly – electric PPSes as the first step. Alongside fuel efficiency and reduction of emissions, innovative PPS can also increase the adaptability of ships to different operating profiles.

The complexity of innovative onboard PPS architectures is increasing due to the addition of several components

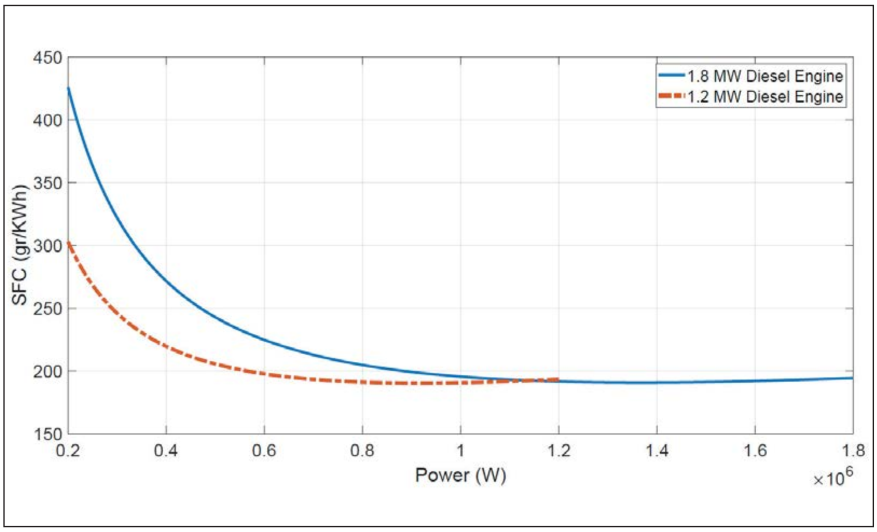


Figure 3: SFC curve of two diesel engines with different power ratings

such as synchronous generators, induction motors, and power conversion modules. The innovative architectures can be divided into two different types: all-electric architectures in which this relationship is formed only through an electrical grid (Figure 1) and hybrid architectures in which the relationship between diesel engine and propellers is established both directly and through electrical machinery (Figure 2). It has been shown that such advanced architectures cannot be as efficient as expected unless advanced control and energy management algorithms are adopted. There has been considerable research increasing the fuel efficiency of ships with these architectures. For more information regarding this work see [12] and references therein.

Ships with advanced PPS architecture are more adaptive to different types of operating profile as they can use diverse types of energy sources for carrying out their operations. Moreover, this diversity provides flexibility in reaching a fuel consumption-based optimal split between the different energy sources' share of generating power. In a vessel train where different types of vessels with different PPS specifications meet to sail at a similar voyage speed, this flexibility and adaptiveness can help to improve efficiency.

The adoption of advanced approaches for the control of the PPS and energy management can lead to a significant increase in fuel efficiency and reduced emissions [13—16]. Furthermore, when it comes to multi-vessel operations, if an intelligent cooperative approach is developed for vessels to collaborate with each other towards the goals of their mission by considering each other's limitations, efficiency and performance can even be further improved.

As an example, in a vessel train, consider two vessels with different engine specifications. The specific fuel consumption (SFC) curves of these vessel are shown in Figure 3. The question then is what speed is best for a platoon that includes these two vessels so that the overall fuel efficiency is maximised? And how can this speed be reached? In the next section, using advanced approaches, a cooperative protocol whereby collaboration between vessels is enabled with the aim of decreasing fuel consumption is introduced.

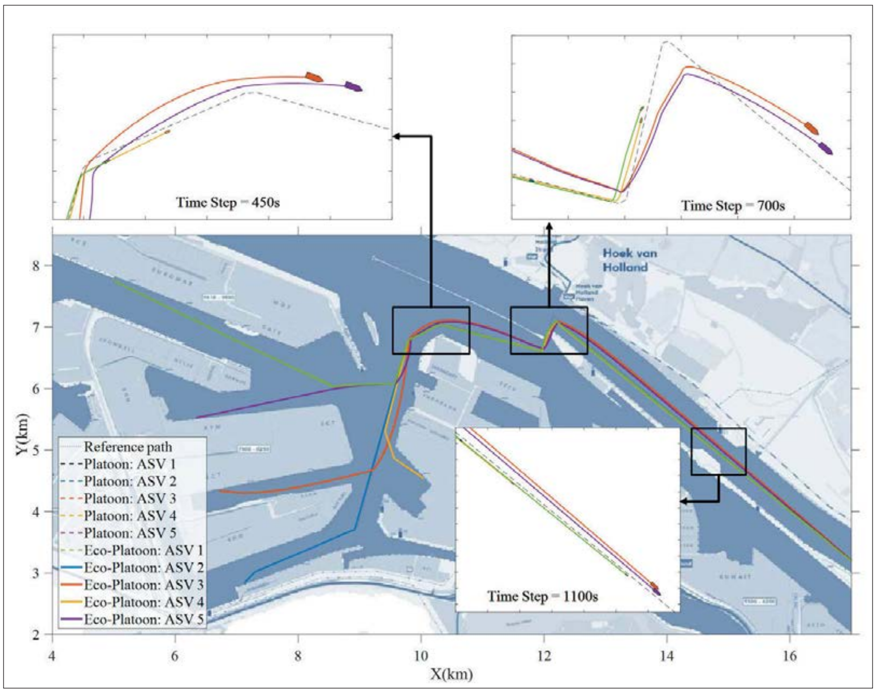
Eco-Platooning for Smart Ships

Ships usually have predetermined origins, destinations and paths, to sail in groups ships should reach consensus on the speed of the platoon. At the same time, ships should avoid collisions with nearby vessels. Thus, in the platoon of vessels, the following needs to be considered at the same time:

1) Trajectory following: attempt to follow the predetermined paths
2) Speed consensus: attempt to keep the same speed with nearby ships
3) Collision avoidance: avoid collisions with nearby ships

In the platooning problem, a vessel controller per vessel makes decisions based on the information provided by sensors and the information it receives from other vessels. An agreement is achieved when the actions of the controller are chosen

Figure 4: Trajectories of the ships in simulation using eco-platooning



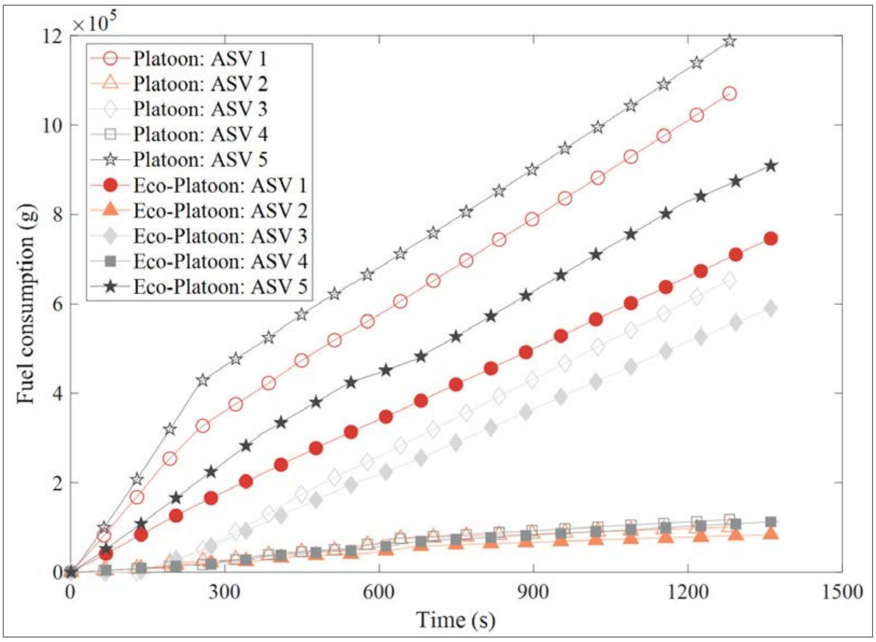


Figure 5: Total fuel consumption of each vessel

based on the information it receives from the controller of other vessels.

In a waterborne platoon, there can be several ships with different specifications regarding ship size, shape, power ratings, etc. As a result, their suitable operating profiles might differ. A fuel-efficient platooning method, eco-platooning, is proposed [17], which involves finding a consensus on the speed for the platoon that is optimal for all the ships subject to their operational objectives and the efficiency specification of their PPS. In eco-platooning, each ship controller proposes a fuel-efficient speed that can make its diesel engine to operate within the efficient region of its SFC curve.

As an example, simulation experiments were carried out for a waterborne platoon consisting of five ships navigating from the different terminals in the Port of Rotterdam to inland waterways. Each ship had different dynamics and engine settings to be considered, and was controlled by an advanced control approach known as model predictive control (MPC) that tries to reach consensus on the platoon speed by negotiating with other vessels through the eco-platooning protocol.

Figure 4 shows the trajectories of the vessels. The ships have similar trajectories in the experiments using eco-platooning protocol and a platooning protocol which does not consider the PPS specifications of the vessels. Total fuel consumption of each ship using two approaches are provided in Figure 5. Table 1 provides the comparison of average speed, average fuel consumption rate (FCR) and total fuel consumption of the experiments using the normal platooning and eco-platooning approaches. The results suggest that a significant amount of fuel saving could be achieved by using eco-platooning. For more information regarding this research work and its results, the reader is referred to [18].

Optimal platooning formations

Another issue in platooning is the positioning of follower vessels in a platoon since the water resistance will be subject to

		ASV 1	ASV 2	ASV 3	ASV 4	ASV 5
National Platooning	Average speed (m/s)	0.42	0.40	0.33	0.37	0.46
	Average FCR (g/s)	152.55	14.37	93.14	16.77	169.28
	Fuel ($x10^5$ g)	10.71	1.01	6.54	1.18	11.89
Eco-Platooning	Average speed (m/s)	0.34	0.37	0.31	0.35	0.39
	Average FCR (g/s)	100.04	11.22	79.29	15.04	121.67
	Fuel ($x10^5$ g)	7.55	0.85	5.98	1.13	9.18
Difference[a]	Average speed (m/s)	-0.08	-0.04	-0.03	-0.02	-0.07
	Average FCR (g/s)	-52.51	-3.15	-13.85	-1.73	-47.61
	Fuel ($x10^5$ g)	-3.17	-0.16	-0.56	-0.04	-2.71
FCR improvement[b]		-34.4%	-21.9%	-14.9%	-10.3%	-28.1%
Fuel improvement[b]		-29.6%	-16.2%	-8.6%	-3.7%	-22.8%
[a] Difference=Eco-Platooning - Normal Platooning; [b] Improvement=Difference/Platooning						

Table 1: Comparison of the simulation results

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- Improvements in manufacturing quality/accuracy/productivity due to computing methodologies.
- Topics not listed above that are relevant to the industry, which are also acceptable.

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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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change due to propulsion and hull effects from the front vessels. As a result, it is vital to find the optimal position for follower vessels where the resistance is minimum. This problem has been investigated at the Maritime and Transport Technology department of Delft University of Technology where different positioning configurations have been tested [18].

The results of these experiments suggest that for vessels with approximately similar size and circular hull shapes, it is favourable to position the follower vessel at an angle of 30° to 50° behind the front vessel. Moreover, the longitudinal distance with the front vessel changes based on the speed of the platoon. Figure 6 shows the optimal placing of the follower vessel at 3.5 knot. The energy consumption of the follower vessel in different positions relative to the front vessel is compared with the energy consumption of a single sailing vessel in Figure 7.

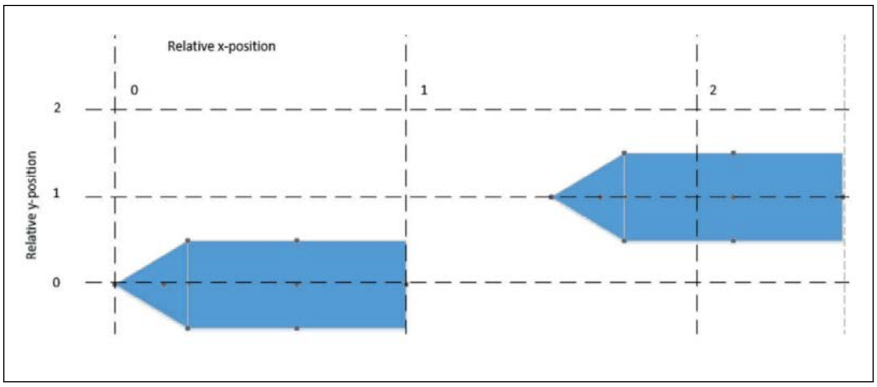

Figure 6: Optimal positioning of the follower vessel at 3.5 knot

Conclusion

In this article, waterborne platooning as an innovative shipping scheme is explained and introduced. Its advantages and disadvantages are mentioned and some solutions are proposed for enabling fuel-efficient vessel trains. Platooning using smart vessels is a novel transport approach which can address several waterborne transport issues. It is in accordance with the concept of autonomous shipping and can lead to increased autonomy and reduced transport costs.

In order to enable waterborne platooning, many issues need to be addressed, which requires extensive considerations by both academic and industrial communities.

Acknowledgment

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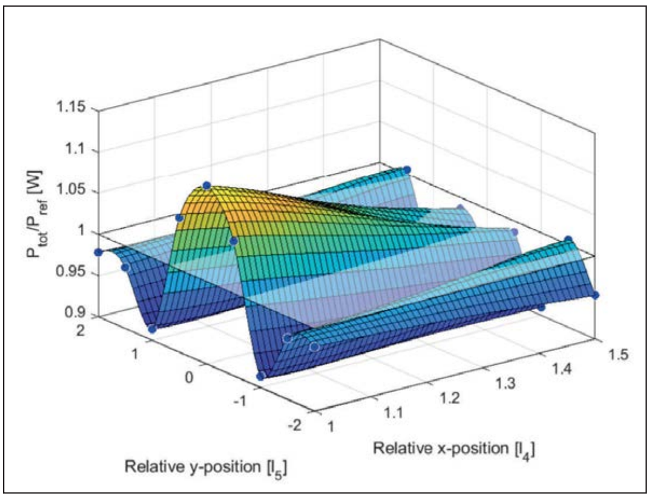

Figure 7: Energy consumption of the follower vessel in different positions relative to the leader vessel and in comparison with a single sailing vessel at 3.5 knot

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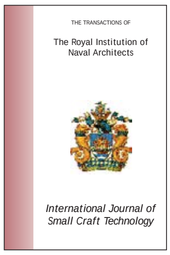

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