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Nor-Shipping 2019

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CEO, Oakwood Agency

Justine Gillen
VP, Marketing, Maritime & Law Intelligence, Informa

Anja Andersen
Senior Corporate Brand Manager, A.P Møller Maersk

Andreas Bodmann
Leading Marketing Professional

Jan-Hein Reeringh
Digital Marketing Manager, Damen Shipyards Group

Rachel Waring
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Programme

The Marketing in Maritime programme will include three key sessions, join us all day or attend just one session to suit your busy Nor-Shipping schedule

Session 1: 09:15-11:30
The digital journey - where are you?

Session 2: 12:00-14:05
The value of the publisher in a data led world

Session 3: 14:55-17:15
Walking in your customers shoes - insights to know your audience

*Full session descriptions can be found online at www.mimcrowd.com/2019

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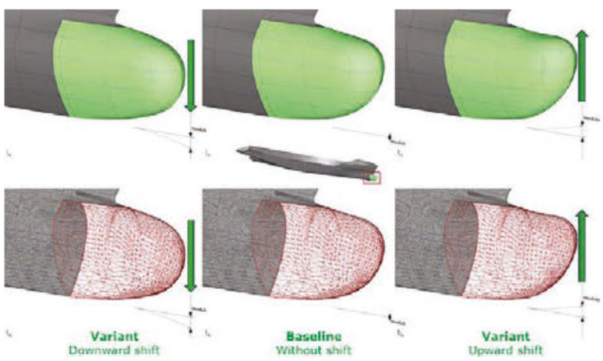

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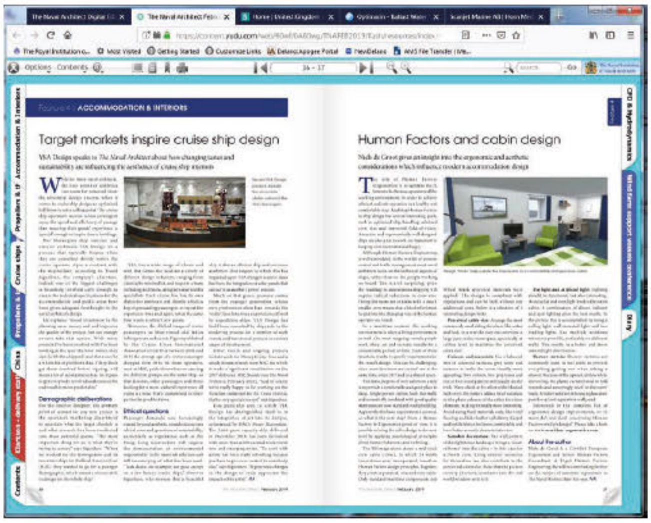

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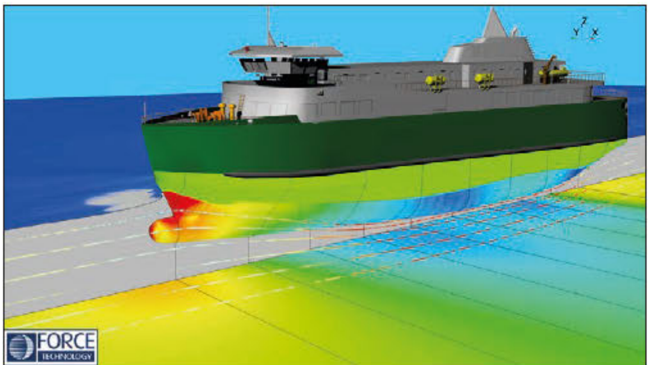

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Safety last?

The *Maersk Honam* fire in March 2018 illustrated the risks of very large containers ships. Image: Indian Coast Guard

The incident that took place onboard the Norwegian cruise ship *Viking Sky* on 23 March, in which 1,373 passengers and crew found themselves adrift in strong winds in the North Sea after an automatic engine shutdown, raises a number of questions.

Initial investigations by the flag administrators Norwegian Maritime Authority (NMA) and the class society Lloyd's Register concluded that the failure of the vessel's four MAN 32/44CR engines was directly caused by low oil pressure. Although the level of lubricating oil in the tanks was within set limits (albeit low), the heavy seas at the time appear to have caused movements which interrupted the supply. This in turn had triggered an alarm and, shortly after, an automatic shutdown.

The NMA has drawn up a general safety notice that shipowners need to liaise with engine suppliers to ensure a continuous supply of oil to critical systems in adverse weather. Additionally, it states that appropriate risk assessments need to be incorporated into safety management systems. But why, if an alarm was triggered, did the engine room not respond to it? Would it not have been preferable to override the shutdown and maintain power in the interests of passenger safety? To what extent has an over-reliance on automated processes contributed to this occurrence or is it an ambiguity between human/machine interaction? *Viking Sky* only entered service two years ago – aren't modern ships meant to be safer?

Only a week prior to the incident, I attended a press briefing by DNV GL, which proved to be timely. It emphasised how safety is in danger of being overlooked in the general rush towards automation, increased efficiency and emissions control. Pointing to a 2018 report by insurers Allianz Global, DNV GL's CEO of Maritime, Knut Ørbeck-Nilssen, said that while total losses reached their lowest count in a decade (94) in 2017, there was no room for complacency. He noted that 75% of losses are still attributable to human error and might benefit from the application of new technologies.

With that in mind, Ørbeck-Nilssen outlined DNV GL's proposals for safety improvements. These include the need to develop broader, more holistic regulations, as well as the improvement of safety culture in general. The class society is also keen to unlock the potential of Big Data to provide deeper insight into incidents and near misses, using platforms such as DNV GL's own Veracity.

There is a particular concern surrounding transparency on the reporting of findings of certain incidents. "The industry as a whole seems to be quite reluctant to share those insights and it takes a long time before these investigations are concluded, reported and made publicly available, and that time lag is waste of good learning," said Ørbeck-Nilssen. He also noted that maritime could learn much from the reporting mechanism in place in other industries, such as aviation and oil and gas, and how barrier management might be applied.

Market forces, not least of which is the growing ship sizes of recent years, are also presenting new challenges to safety. Of these, the greatest concerns surround container ship fires. The March 2018 fire in the forward hold of the 15,226TEU *Maersk Honam* in the Arabian Sea, which resulted in the death of five seafarers, realised the worst fears of many.

I listened to very animated debate on the same topic at a conference of the International Salvage Union only a day earlier (see p.17). Some delegates argued that logistics companies have a lot to answer for, as insurers typically estimate around 27% of container cargo is misdeclared. The propagation of a container ship fire represents a particular challenge to salvors; firstly, stabilise the situation (bear in mind that in the event of chemical fire it may not even be clear what substances they are dealing with), minimise cargo loss and save as much as possible of the ship. In the case of the *Maersk Honam* it was more than a month before the fire was fully extinguished. Only two weeks later, a less serious fire occurred on the *Maersk Kensington*. The Danish operator has since published revised guidelines advocating a risk-based approach to dangerous goods stowage, which it has also presented to IMO.

Safety legislation will always, to some extent, be reactive for the simple fact that it's impossible to consider all eventualities. That's especially true when it's constantly being outpaced by technological advances. In that regard the paradigm shift represented by remote and autonomous shipping, and the careful deliberations required before it can be implemented on a wide scale, may actually serve as a wake-up call. Conversely, there has also been a prolonged and willful neglect in the interest of expediency and economising, however, there can be no excuse for persistent and potentially fatal problems being willfully ignored. There's a laudable reluctance to attribute blame when it comes to maritime accidents, but ultimately the only solution will be increased accountability across the industry. *NA*

Wind propulsion

French ro-ro wind project gathers momentum

Two major manufacturers have pledged their support for the wind assisted ro-ro cargo project, Neoline.

The French agricultural and industrial vehicle specialist, Manitou group, as well as the sail and motor boat manufacturer, Beneteau group, have announced their interest in partnering with Neoline to transport their products from Europe to America.

The consideration of Neoline by Manitou and Beneteau follows a three-year partnership Neoline signed with the car-maker Renault last November.

Founded in 2015, the French start-up is developing a high-efficiency 136m long ro-ro vessel equipped with 4,200m^2 of sails, merging technical maritime transport solutions with sport sailing. The vessel offers shippers a clean and sustainable solution, primarily using wind propulsion in combination with economical speed and optimisation of energy mix.

The planned line will connect St-Nazaire, France with the American east coast and Saint-Pierrea and Miquelon, a French archipelago located off the coast of Canada.

The industrial-sized sailing freighter will specialise in rolling and oversized goods. In a statement, Beneteau group said it had worked with Neoline to "define some of the ships' features, including their exceptional door height of 9.8m".

Neoline also says it plans to equip their vessels with movable decks with dimensions and resistance that are suited to large machines like those produced by the Manitou group. Two ships of this model are expected to be built and completed by 2021.

With 80% of Manitou group's revenues earned internationally, the group plans to transport more than 1,000 machines by ship from across the Atlantic in 2019.

"Neoline's proposal is a perfect fit for our operational needs. It is also viable in terms of energy consumption, saving an estimated more than 4,000tons of CO_2 per year", said Augustin Merle, transport and logistics manager at the Manitou group.

The Neoline concept is equipped with a duplex rigging and anti-drift fins

"With this service, we will maintain similar delivery times, while optimising pre-routing from our factories in Grand Ouest to the port of Nantes - Saint-Nazaire."

Greenhouse gases

Low carbon shipping group wins further support

The Panama Canal Authority and A.P. Moller-Maersk are the latest organisations to enrol in the IMO-backed Global Industry Alliance to Support Low Carbon Shipping (GIA).

The newest members officially joined the GIA during its fifth taskforce meeting held last month at the IMO headquarters in London, bringing the group to a total of 18 members.

The Panama Canal is the first Latin American organisation to join the GIA. It has previously been recognised for its sustainability initiatives and efforts to reduce Greenhouse Gas emissions, with projects such as the waterway's expansion in 2016.

Maersk is only the second container shipping line to join the alliance, the other is MSC. Last year, the Danish-headquartered carrier pledged to reach zero carbon emissions by 2050 and recently announced that it will conduct a pilot test of the long-distance viability of biofuel.

Launched in 2017, the GIA is a public-private partnership of leading maritime organisations, shipowners, operators, classification societies and others working to address the industry's transition to a low carbon future.

As well as signing up its new members, the meeting discussed on several projects, including the validation of performance of Energy Efficiency Technologies, and formalised the extension of the GIA until 31 December 2019.

Noise pollution

LR releases noise notation for ships in port

The class society Lloyd's Register (LR) has introduced the industry's first airborne noise emission notation (ABN) and ShipRight procedure.

In efforts to meet the rising demand for a standardised method of controlling airborne noise emissions from ships, the notion will enable ports to better monitor overall noise levels from ship calls.

It defines a set of limit levels for airborne noise emissions from ships, helping port authorities determine which and how many ships can access the most noise sensitive areas of the port.

Ports worldwide, particularly those located in residential areas, have received an increasing number of excessive noise complaints. The problem came into

focus two years ago with the establishment of the Noise Exploration Program to Understand Noise Emitted by Seagoing Ships (NEPTUNES). Created by the Port of Rotterdam Authority, the group advocates for the reduction of shipping noise.

A port is typically considered an "industrial plant" in respect to noise legislation and ships are considered noise sources that are counted towards the port's overall noise emissions. Although ports are accountable for the level of noise emitted from ships entering or using the port, there are currently no regulations for controlling the airborne noise produced by individual ships.

The new notation gives ports the authority to specify that ships require a certain ABN notation to stay in noise sensitive areas of a port. Likewise, it allows shipowners to verify that their vessels have controlled airborne noise emissions.

Additionally, the report addresses airborne noise levels along inland waterways. Currently, maximum noise levels for inland waterways are specified in the Directive (EU) 2016/1629, but the ABN notation will ensure ships comply with these requirements.

The new notation defines five limit levels for airborne noise emissions: super quiet, quiet, standard, inland waterways, commercial.

Developed with the assistance of yard representatives and port operators, the notation also outlines how compliance can be ensured at the design stage and provides tools to calculate expected noise levels.

Marine pollution

UN advisors publish marine plastic pollution report

The fight against marine plastic pollution has stepped-up with the launch of a new set of guidelines addressing the monitoring of plastics and microplastics in the world's oceans.

Published by the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), a body which advises the UN on marine protection, the publicly-available guidelines aim to harmonise environmental monitoring methods.

Created in response to the lack of internationally agreed upon monitoring practices, the report provides practical advice for national and international organisations responsible for managing the marine environment, including those with little experience in the field.

The *Guidelines for the monitoring and Assessment of Plastic Litter and Microplastics in the Ocean* outlines: what to sample, how to collect data and how to assess plastics on the seafloor, the sea surface and on the shoreline. It also recommends the best ways of designing and establishing programmes to monitor the abundance of marine plastic debris.

Additional sections of the report cover citizen science programmes, recommending the best ways for members of the public to help record the types of plastics found in the oceans.

Accurately assessing the scale of the world's marine plastic litter problem has been difficult until now, without any globally standardised guidelines for organisations to rely upon. Most data previously available was gathered from individual surveys and research projects, rather than monitoring programmes, making the comparison of information difficult.

The report stresses that the need for harmonised data has reached a critical point, as the UN Sustainable Development Goal of reducing ocean pollution by 2025 draws closer. With sampling protocols in place, it will be easier to reduce the barriers of data sharing and develop a reliable international data management system.

The hope is that these new monitoring methods will showcase the true scale of the plastics problem and help identify how reduction protocols, such as the banning of single-use plastics, will make an impact.

Polar shipping

Wärtsilä to design and equip Aker Antarctic vessel

The Finnish tech giant Wärtsilä, has secured a contract to design a new energy efficient transport vessel that will operate in Antarctic waters.

Priced at US$65 million, the 168m long, 20,300 dwt multipurpose vessel will be fitted with Wärtsilä's integrated propulsion and hybrid solutions, and is said to have a minimal impact on the environment.

In order to face the sensitive and challenging Antarctic conditions, the Polar-Code-compliant vessel incorporates the latest environmentally friendly technologies. It will be powered by Wärtsilä's award-winning 31 engine and two Wärtsilä 20 engines for auxiliary power. All engines will be fitted with Wärtsilä's NOx Reducer to prevent nitrogen oxide emissions when operating in diesel mode.

Wärtsilä will also deliver the power distribution system, including hybrid drives and a battery package. Addition-

The Aker BioMarine vessel designed by Wärtsilä will travel to the Antarctic ally, the vessel will feature frequency-controlled thrusters, to avoid zero pitch loss and reduce underwater noise.

Contracted by Norway-based Aker BioMarine as a replacement for their existing vessel, *La Manche*, it will be constructed in China, at CIMA Raffles, Yantai yard.

The ship will carry supply goods as well as krill products from krill harvesting vessels. For this, a custom cargo handling system, provided by Aukra Maritime, has been developed to halve the time needed to load and unload packed krill.

Wärtsilä and Aker BioMarine are working together to address the operational needs previously encountered by *La Manche*.

The vessel is expected to be completed in 2021.

Sulphur reduction

HMM opts for scrubbers on VLCS series

Hyundai Merchant Marine (HMM) has opted to install scrubbers rather than LNG bunkering on its 12 mega containerships, due for delivery in the second quarter of 2020.

Of the dozen 23,000TEU boxships, seven will be built at Daewoo Shipbuilding and Marine Engineering (DSME) and five at Samsung Heavy Industries.

Valmet, a Finland-based technology developer, signed a deal with the South Korean shipping company to supply seven scrubbers for the newbuilds at DSME.

The systems will include tailor-made hybrid systems for the main engine and generator engines. The exhaust gas will be washed with seawater in open-loop mode and recirculate water and alkali when in closed-loop mode.

HMM will also fit scrubbers on another eight 15,000TEU containerships that will be constructed at Hyundai Heavy Industries (HHI).

In preparation for the IMO's 2020 low-sulphur regulations, the Korean shipowner has established a fund for scrubber installation, a total investment worth KRW153.3 billion (US$135.8 million). The shipowner itself will contribute KRW46 billion and Korean Ocean Business Corporation will provide a guaranteed loan of KRW62.3 billion. The remaining KRW45 billion will be invested by Hyundai Corporation, SKTI, Hyundai Global Service, DSEC, and Panasia.

HMM has plans underway to retrofit scrubbers on its 19 containerships currently in operation by the first half of 2020. The five companies invested in the newly established fund will be prioritised for the supply contracts. *NA*

Going Dutch on scrubbing, alternate fuels, cruise ships and autonomy

There was a distinctive Dutch flavour to many maritime news stories throughout March, writes Malcolm Latarche

Although the Netherlands may be best known for marine civil engineering and small cargo ship construction, the latest news out of the country highlights its innovation in other sectors. Many of these news items are also connected with the IMO 2020 regulation on sulphur, which is perhaps appropriate since it was Netherlands-based CE Delft that produced the report on which the IMO based its decision.

Amongst the latest stories was an announcement by scrubber maker Value Maritime, stating that Visser Shipping has opted to install its equipment on three container vessels.

Compared with other recent scrubber orders, three systems may not seem like much. But the Value Maritime scrubber brings innovation to the technology that could see a much wider uptake in scrubbers than originally predicted. It is a modular system that is mostly prefabricated and contained in a 'plug and play' housing unit, reducing installation time.

Importantly, it is also designed to be re-usable so that if installed on an older vessel that is eventually sent for scrapping, it can easily be removed and fitted onto a newer ship. An additional factor in its favour is that it was developed with smaller ships in mind. The three variants currently being marketed are for three-, six- and nine-megawatt engine sizes. Visser has opted for open-loop systems that are also 'hybrid-ready'.

For ship operators that do not want to go down the scrubber route, other recent Dutch developments could be more interesting. On 23 March, the *CMA CGM White Shark* was bunkered with a sustainable biofuel produced by GoodFuels, as part of a joint project between IKEA Transport & Logistics Services, CMA CGM, the GoodShipping Program and the Port of Rotterdam. (See page 16 for more infomation.) Rotterdam is a major bunkering port and will be one of those where 2020 compliant fuels should be readily available.

Another Dutch alternative fuel initiative, this time involving methanol, was announced in late February. The project involves a number of shipowners including Boskalis, The Royal Netherlands Navy, Van Oord and Wagenborg Shipping as well as shipbuilders, engine manufacturers and other equipment suppliers. Rotterdam and Amsterdam ports will also be involved in looking at the supply and infrastructure side of using methanol as a fuel. The project is supported by TKI Maritime and the Netherlands Ministry of Economic Affairs and is expected to be completed within two years.

Looking towards the future and hydrogen, Nedstack – a Dutch manufacturer of PEM fuel cells – kick-started a partnership with GE Power Conversion aimed at developing hydrogen fuel cell systems for powering zero-emission cruise vessels. So far, Nedstack and GE have designed the concept for a two-megawatt hydrogen fuel cell power plant on an expedition vessel. They claim the review result has been highly positive and plausible. Their ultimate goal is a truly zero-emission system that will enable the world's first sustainable, clean cruise ships.

Despite the Netherlands historic connection with cruise ships, it has not built ships of the type for some years now. However, last month the Netherlands-based shipbuilder Damen – which has harboured ambitions to enter the expedition cruise sector for around two years now and launched a new subsidiary Damen Cruise last year – finally made a breakthrough with an initial order placed by Norwegian operator SeaDream Yacht Club.

Although likely to be named Mega Yacht, the 155m vessel is much more of a cruise ship and the size and specification is in line with other ships of the new expedition cruise ship type. The Mega Yacht will be prepared to operate in destinations, including polar and tropical, around the world. As such, the vessel will boast ice class Polar Code 6 credentials. The Dutch connection will be limited to the design of the Mega Yacht though, as the ship will be completely constructed and outfitted, including the interior, at the Damen Mangalia yard in Romania.

Finally, the Netherlands has also joined the club of states experimenting with autonomous ships and remote operation. A joint industry project involving 17 organisations under the title Autonomous Shipping was established in the Netherlands two years ago. In mid-March, the project's first autonomous operation trials were carried out in the North Sea of Den Helder.

A total of 11 scenarios were run in which *SeaZip 3*, a fast crew boat fitted with collision avoidance technology interacted autonomously with two other vessels involved in the trials. These scenarios are the outcome of research by Technical University of Delft, MARIN and TNO. The scenarios were first tested in the MARIN simulator centre in Wageningen. *NA*

Ballast water treatment

Bio-UV wins new orders from MSC Cruises

Bio-UV Group has secured a contract with MSC Cruises to supply its Bio-Sea ballast water treatment system for two world-class cruise ships.

The ships, which are currently under construction at Chantiers de L'Atlantique shipyard in St. Nazaire, France, will each be fitted with a Bio-Sea B02-0300 skid-mounted unit. These ultraviolet light water treatment systems are capable of treating ballast water flows of 300m^3/h and will feature an embedded power management cabinet for easy operation.

The order follows the successful installation and operation of similar units aboard MSC's Meraviglia class of cruise ships, the most recent of which was delivered on the *MSC Bellissima*. In total, four Meraviglia-class vessels will run Bio-Sea systems.

Scheduled for 2022 and 2024 the ships are MSC Cruises' first vessels to operate on LNG as marine fuel.

Bio-Sea technology – specifically a 250m^3/h flow rate capacity unit – has also been selected by Celebrity Cruises for their four Edge Class vessels, including one unit that is already in service.

The France-based group has supplied its Bio-Sea ballast water treatment systems to over 100 vessels worldwide to date. As reported in last month's *The Naval Architect*, the company is targeting a market share of up to 5% by 2022 (approx. 2,500 vessels) and had already received more orders by the end of January than the entire previous year.

Propulsion

ABB to power first Chinese-built cruise ship

ABB has struck a deal with Shanghai Waigaoqiao Shipbuilding Co., Ltd to supply an integrated power and propulsion package for China's first domestically built cruise ship.

The Swiss technology group will deliver two Azipod steerable propulsion systems, which it says can cut fuel consumption by up to 15%, reduce noise and vibration and offer 360-degree manoeuvrability, for the 323m vessel.

In addition, the supplied package will include an electric power plant concept with electricity generators, main switchboards, distribution transformers and a propulsion control system for moving the Azipod units from the bridge. The Azipod units can be fully integrated with the electric power plant and propulsion control system, ensuring optimal energy efficiency.

The Azipod steerable propulsion system

The digital system will also provide remote diagnostic capabilities.

Due for delivery in 2023, the 5,000 passenger vessel will be designed to suit the tastes of Chinese cruise travellers. Once complete, it is set to become part of a fleet of Chinese-constructed cruise ships operated by CSSC Carnival Cruise Shipping Limited.

China's rapid developments in domestic shipbuilding paired with its vast consumer market is generating an increasing demand for cruise travel.

According to the Cruise Lines International Association, the number of Chinese cruise travellers is predicted to rise to 8-10 million annually by 2025.

The country is developing into one of the world's leading cruise nations with an industry that is expected to rival that of the United States over the next decade or two, reports the China Cruise and Yacht Industry Association.

Performance management

MAN unveils new digital platform

German-headquartered MAN Energy Solutions has launched a new digital platform, dubbed MAN CEON, that provides real-time data analysis.

The platform is designed to collect and evaluate operating and sensor data, while enabling the continuous monitoring of marine engines. It integrates data and information from MAN machinery as well as its operational environment and uses intelligent analysis tools for evaluation and forecasting.

Customers can access the platform via a web application on their PC or by using a mobile terminal after connecting their installation to MAN CEON. Data is secured through encrypted transmissions and multi-level authorisation during login.

Promoted as the backbone of MAN's digital services, the platform is also scalable with a data-processing power that "exceeds that of many major social media platforms." It has the capacity to monitor several thousands of customer installations in parallel, as cloud-based technology and algorithms automatically identify and report issues.

The platform will become standard to all new MAN engines, turbines and compressors from this year, and can be retrofitted to existing machinery within hours.

Operating data of all systems and ships connected to the CEON network can be transmitted to MAN service centres in real time to help customers with maintenance.

MAN CEON is even able to monitor small subcomponents and provide high-resolution data on demand.

Behind the platform is the MAN Energy Solutions' digital team, which was established in 2016 in order to boost the company's focus on digital services.

Wastewater discharge

IMO urged for MARPOL sewage rethink

German group ACO Marine has joined other wastewater treatment system manufacturers and environmental organisations in calling for a revision of MARPOL Annex IV – the regulations for preventing sewage pollution.

The organisations are seeking to verify the performance and discharge criteria of onboard sewage treatment systems. While there are existing rules in place for validating discharge parameters, they only relate to type-approval testing on land-based establishments. Once a system has been installed and becomes operational, there is no further enforcement of the wastewater discharge criteria.

"The main contention is that we believe there are type-approved systems in operation at sea that are scientifically incapable of treating sewage waste," said Mark Beavis, ACO Marine's Managing Director.

Although the rules were previously tightened with the introduction of MEPC.227(64) and the use of dilution water limited during performance tests, the current guidelines do not explicitly prohibit sludge-free systems. Consequently, these apparent sludge-free systems are regularly certified and are putting competitive pressure on valid technologies to copy such claims.

A paper co-authored by Beavis states: "Some manufacturers claim their sewage treatment plants do not produce sludge. Unfortunately, conformity assessment bodies have approved their equipment. But they have certified impossibilities and created certified 'magic boxes'. These systems contravene science."

Yet, these 'magic boxes' are easy to spot, given that there are no sludge separation features within the treatment process.

Authors of the paper believe that this type of approval regime is in "contradiction to the IMO's intentions".

"Certificates have become licenses to pollute. Something is very wrong," the paper states.

There is now a call for the IMO and assigned assessment bodies to acknowledge the issue, undertake reviews and conclude what is happening in order to established protocols, which may prevent these non-conformities from reoccurring.

Ship safety

Viking's LifeCraft gets Danish endorsement

The Danish Maritime Authority (DMA) has approved the Viking LifeCraft Survival Craft system as a Novel Life-Saving Appliance (NLSA) after it successfully passed its heavy weather trials last November.

Developed by the Denmark-based company Viking Life-Saving Equipment, the survival unit is an innovative hybrid system that combines the advantages of lifeboats and liferafts (see *The Naval Architect*, October 2018). Its approval marks the first time a survival craft, which is not a variation or adaptation of a traditional lifeboat, has been award NLSA status by the DMA.

The system is made up of four inflatable Viking LifeCraft survival crafts, each with a capacity of 203 persons, and a full self-contained stowage and launch appliance that may be placed on deck or built into the ship's side.

The survival crafts are highly manoeuvrable with four independent electric engines at its corners. They are capable of quickly turning 360 degrees on the spot – a feat unmatched by conventional motor-propelled survival units – which allows the craft to clear the ship's side in an emergency evacuation.

During the system's heavy weather sea trial, it withstood unusually intense testing conditions, with wind gusts and waves up to 50% greater than the stipulated testing requirements.

Viking hopes that the survival craft will enhance passenger safety and improve large scale ship evacuations.

But before the Viking LifeCraft can be released on the market, it still needs NLSA approval for the chute element of the system, which is scheduled for August 2019. *NA*

Viking's LifeCraft concept has been in development for 10 years

Pilot project shows significance and scalability of biofuels

Pioneering biofuel company, GoodFuels, trials sustainable fuel alternative in landmark bunkering

CMA CGM White Shark was bunkered with GoodFuels biofuel on the 23 March

With the IMO's 2020 sulphur regulations on the horizon, shipowners face a growing list of options to ensure their vessels remain 'seaworthy'. Yet the most popular solutions – LNG, scrubbers, low-sulphur fuel oil (LSFO) – all have significant drawbacks. There is an uncertainty about the availability of LSFO, major ports are banning open loop scrubbers, while retrofitting a vessel for LNG is costly and the bunkering infrastructure still limited.

But there's another option and its proponents believe it could offer the easiest and most viable way of meeting the sulphur cap while also lowering CO_2 emissions – biofuel.

Last month, a partnership between the Swedish furniture retailer IKEA, CMA CGM, the sustainable initiative the GoodShipping Program and the Port of Rotterdam saw the world's first ocean freight bunkered with marine bio-fuel.

The refuelling of the *CMA CGM White Shark* – a 5,095 TEU container vessel – represents an attempt to scale up the use of sustainable low carbon marine biofuels.

Produced by the Dutch-based company, GoodFuels, the biofuel is expected to cut up to 90% of CO_2 emission versus its fossil fuel equivalents and "virtually eliminate" sulphur oxide emissions.

Established in 2015, the company worked for three years to develop the 'drop-in' biofuel, testing over 20 different variations in the process. Today, more than 300 ships are fuelled in some manner using the mixture derived from waste cooking oils and forest residues.

For some vessels, this means being entirely bunkered with the biofuel, while others opt to bend the highly compatible fuel with conventional low-sulphur heavy fuel oils. The fuel mimics the characteristics of heavy fuel oil (HFO), so no engine modifications are necessary. It can simply be dropped into any type of vessel.

"It's basically a new category [of fuel]: a low-carbon, zero-sulphur fuel," says Dirk Kronemeijer, CEO and founder of GoodFuels.

Although the biofuel is functionally very similar to HFO, its energy density is slightly less. Therefore, in order to meet the same energy content as HFO, the company supplies more fuel to their clients.

"If we want to decarbonise all IKEA sea freights, say for example that's 10,000 tonnes, we probably have to deliver in the range of 11,000tonnes," says Kronemeijer.

A professed "green oil guy", Kronemeijer set up the company after initially working with sustainable jet fuel. He discovered streams of potential feedstocks, which were deemed unsuitable for use by the aviation industry, would be ideal for a marine combustion engine.

GoodFuels original biofuels were created only using waste cooking oil but to improve the product's scalability, forest residues from paper and pulp production in Scandinavia were later added. The company plans on exploring the potential of urban waste streams as well as waste plastics that are no longer recyclable as part of their feedstocks.

"We have to get rid of this HFO, that's the world's number one challenge. Ideally, we have to do it in such a way that we decarbonise straight away, that is of utmost importance, and we are very happy that we can contribute a little bit towards that goal with our fuels," said Kronemeijer.

The company first brought the fuel to the market last year with the Danish company Norden. Together they tested the fuel on a 37,000dwt Handysize product tanker vessel, the *Nord Highlander*, during a voyage from the Netherlands to Estonia. Since then, GoodFuels has begun scaling rapidly, partnering with VARO Energy to improve the availability of biofuel for deep sea vessels. To date, they have installed bunkering infrastructure in Rotterdam, Amsterdam and Antwerp.

Currently, the biggest roadblock for the biofuel is balancing its price while expanding its bunkering locations. The difference between the availability of the biofuel and LNG, Kronemeijer explains, is that "we want to be as affordable as possible, meaning we are mainly operating in those areas where carbon really matters and there are incentives available stimulating low-carbon fuels."

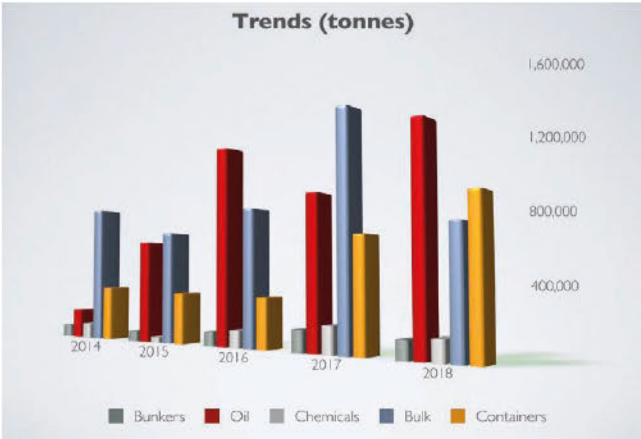
The company has benchmarked the biofuel's price with LSFO, so in a port like Rotterdam where conditions favour biofuel, there is only a modest premium, says Kronemeijer. GoodFuels also regularly works with the GoodShipping Program, through which cargo owners pay to decarbonise their sea freight, rather than the premium of the biofuel. *NA*

ISU underscores its importance to environmental protection

The salvors union finds itself adjusting to a new social paradigm, but there are also growing concerns about the causes behind container ship fires

Over the past few years the International Salvage Union (ISU) has sought to reposition itself in a changing maritime environment. The Lloyd's Open Form salvage contract (LOF) – the standard contract between the shipowner and salvor in the event of an incident requiring intervention – has been in decline as modern communications allow shipowners and marine insurers alike to assimilate more information faster. This means the emergency response can be tailored accordingly and avoid costly salvor fees for services, for example for towage, which may not have been required. Increasingly the preference is for bespoke, fixed price services, greatly diminishing the salvors earnings from any operation.

These industry changes prompted the ISU to publish a revised strategic plan last year, acknowledging that while LOFs still had an important function, the days when over a hundred or more such contracts might be signed were probably over. Instead, the ISU is keen to promote the wealth of expertise and experience its members can bring to salvage operations, particularly with regard to pollution prevention.



The trends of ISU's survey on potentially polluting cargo. Containers were calculated to have a nominal weight of 15 tonnes per TEU

"We understand we're working in a new social paradigm in which protection of the environment is absolutely essential," ISU spokesperson James Herbert told delegates at ISU's Associate Members Day in London on 20 March. "Commercial salvors save lives, save property and mitigate risk in advance through our work with owners and insurers. And of course we reduce loss if the worst happens. But we also want people to understand that the work our members do facilitates world trade."

Herbert highlighted a number of cases, such as the 2016 stranding of the 19,000TEU container ship *CSCL Indian Ocean* on the River Elbe, which might have blocked the Port of Hamburg if not for speedy towage intervention. "This took a huge amount of the resources of ISU members, including 12 or so tugs and a significant amount of dredging to get [the ship] out."

The emphasis on economising, Herbert stressed, had the potential to one day come at the cost of some kind of major disaster. ISU members, however, could provide a "gold standard of high quality engineer solutions", ranging from the relatively basic cleanup of crude oil from a beach to thermal imaging of a shipwreck on the seabed that may be leaking bunker fuel.

For the past 25 years, the ISU has conducted an annual Pollution Prevention Survey of its members, in which salvors return information on services they've conducted over the previous 12 months and the quantities of potential pollutants (cargo and bunker fuel) involved in the operations. More recently, the scope of the survey, which originally focused on oil cargoes, has been expanded to include other pollutants such as containers. "Containers often contain pollutants and if they go overboard they also become a danger to navigation, so with the growth in the container trade it seemed sensible to record them," said Herbert.

The statistics for the latest survey, conducted in 2018, appear to support this decision. While the number of incidents concerning vessels carrying crude and refined oil products was up to 1,302,988tonnes from 933,198tonnes in 2017, such fluctuations can often be attributed to one or two extra incidents across the year. However, the sharp rise in containers involved in salvage cases, measuring 59,874TEU from 45,655TEU a year earlier, is indicative of a growing trend reflected by the increasing number of container ship fires.

Concerns surrounding container ship safety were a recurring theme of the day's event. Salvage expert Nick Sloane spoke about his experiences firefighting large boxships. He observed that with reduced crew numbers there is often limited contingency to deal with an incident and that the firefighting operation itself increasingly becomes a process of carefully managing the fire which, with such densely packed cargo, can potentially take months to finally extinguish.

The common consensus was that misdeclared cargo, in regard to the container ship industry as a whole, was something of the elephant in the room. Nicola Pryce-Roberts of Solent University's maritime faculty suggested that the issue is far more serious than commonly understood. "I gave a presentation to a logistics company about what would happen if there was a large container ship fire and the conversation was quite chilling as they were largely ignorant. There needs to be a wholesale education programme from the shipping industry generally about the dangers." *NA*

Developments in the inland waterways fleet

Bas Joormann, Principal Specialist at Lloyd's Register, provides a brief overview of some current developments in inland shipping

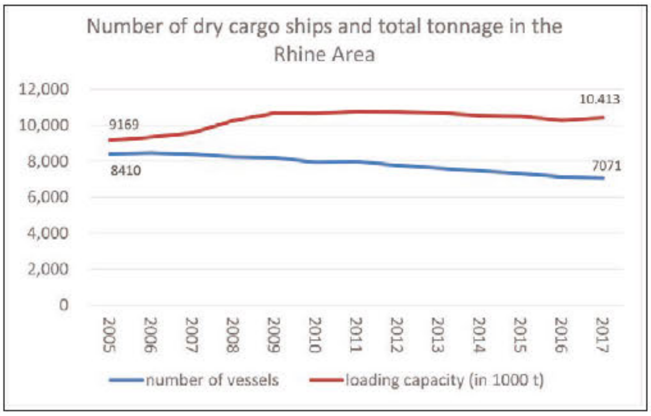
Traditionally, inland navigation in Western Europe has been an important means of transport that plays a crucial role for various economic sectors. Navigation on the Rhine and secondary rivers is the most significant. Since the opening of the Main-Danube Canal in 1992 – the connection between Rotterdam and the Black Sea – transport has increased further. Despite the growth in rail and road transport, passage by inland waterway vessel still occupies a prominent place in Europe. Over the past 25 years, inland waterway transport has increased by an average of 1% per year.

When the maximum permitted dimensions of inland vessels were extended to a length of 135m in 1995, the number of large to very large vessels increased considerably. During the first decade after this only slightly larger ships were built, but since 2005 it has become more the standard than the exception to build ships of 135m and a breadth of up to 22.90m.

As can be seen in Figures 1 and 2, the number of ships in the fleet has decreased while the total tonnage has increased. The decrease in the number of vessels applies primarily to dry cargo vessels, while the number of tankers has remained the same. The average tonnage of the tankers has therefore risen considerably.

Hundreds of new ships were built from 2006 to 2010, during which time China, in particular, became a major supplier of hulls. After 2010, the newbuild market stabilised with an average of 50 newbuild vessels per year. Since 2016, however, an increase in new construction can be observed again, especially in tankers and passenger ships.

The renewal of the tanker fleet is related to an increasing demand for transport, but also to the phasing out of the single-hull tankers. Under the European Agreement for the International Transport of Dangerous Goods by Inland Waterways (ADN), as of 31 December 2018, few dangerous goods may be transported with single-hull tankers.



Figures 1: Number of dry cargo ships and total tonnage

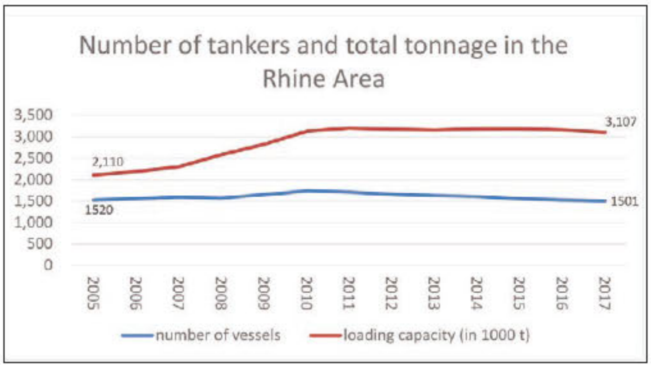


Figure 2: Number of tankers and total tonnage

Many of these vessels have now either been demolished or converted into double-hull tankers or barge vessels.

According to figures published by the three recognised inland navigation classification societies, there are currently around 1,100 double-hull tankers, 640 of which are in the Lloyd's Register class, and the remaining almost equally divided between Bureau Veritas and DNV GL. The other tankers listed in the chart are still single hull or (smaller) bunker boats.

The share of Dutch ships remains high in both dry cargo and tankers. Construction of these ships is mainly carried out for Dutch owners, and to a lesser extent for Belgian and German owners. Of the vessels above 3,000tonnes, 75% belong to Dutch owners and 25% to Belgian owners.

Approximately 95% of these new ships are being built or completed in the Netherlands, with part of the hulls coming from Eastern Europe and China over the last two years.

In addition to the dry cargo ships and tankers, new constructions largely consist of cruise ships. With the opening of the Main-Danube Canal, the sailing area for these ships has increased enormously.

Green Transport

Transport by inland vessel is a clean method of transport. Compared to road and rail transport, the burden on the environment per tonne-kilometre is much less. However, developments within the field of green transport in these other sectors are accelerating quickly and inland shipping is in danger of losing its position in this regard.

There are plenty of steps being taken though to make inland shipping greener.

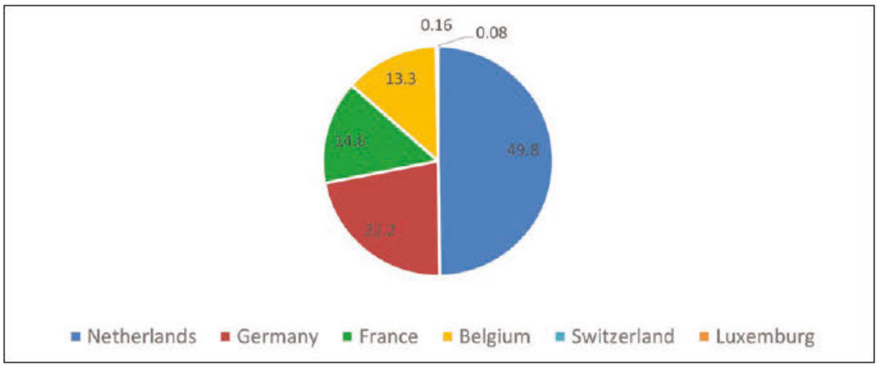


Figure 3 (above): Distribution of dry cargo ships by nationality (status at the end of 2017)

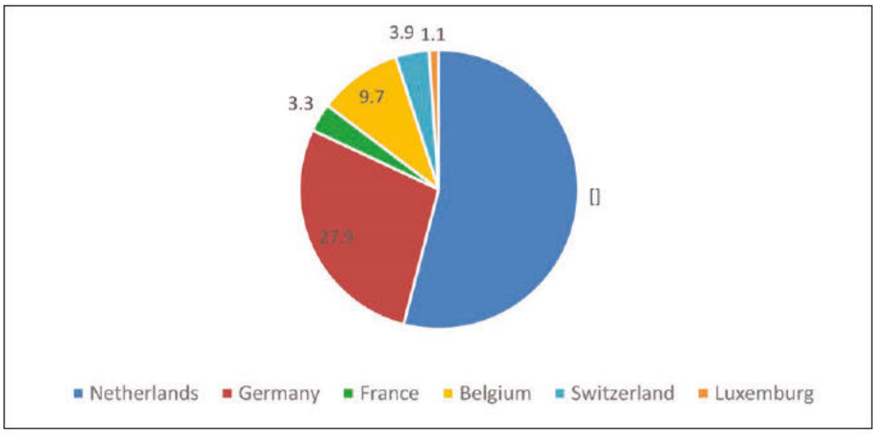


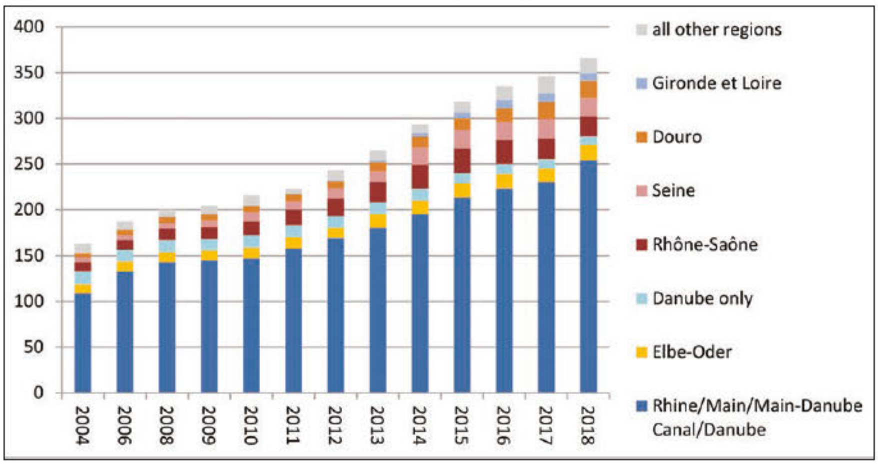
Figure 4 (below): Distribution of tankers by nationality (status at the end of 2017)

This applies to both new construction and existing ships. The use of alternative fuels is an obvious measure here. But the further optimisation of ship shape, weight reduction, fuel saving through 'just in time' sailing, and the scrapping of unused vessels are also contributing to the 'greening' of the fleet. In 2014, around 50% of newbuilds had at least one greening measure. As of today, that percentage is above 80%.

The need to reduce emissions also stems from the increasingly stringent requirements that cities and ports impose on passing and/or visiting ships.

Ten years ago, LNG was introduced as an alternative fuel for inland vessels. Since then, 15 ships have been built or converted for use of dual fuel or full LNG, while a further dozen ships with dual fuel propulsion are under construction. The fact that there isn't more is mainly due to the high costs of the LNG installations and that the price difference compared to diesel has shrunk in recent years.

Figure 5: Number of river cruise ships divided by sailing area



Newbuild vessels have also been launched with hybrid propulsion. Depending on the required load, one or the other propulsion option is then used. In addition to the traditional diesel-electric propulsion, a combination of diesel engines and electric motors that directly drive the propeller shaft is also used. A significant fuel saving can be achieved by adapting the power supplied to current demand.

Currently, there is also interest in fully electric propulsion using batteries or hydrogen fuel cells. Various pilot projects are under development and it is expected that the first ships equipped with this will be put into service in the coming year. Fully electric sailing is especially interesting for ships that sail on short journeys. With the further development of the capacity of batteries, fully electric sailing will certainly be possible in the future for longer journeys.

Regulations

The development of the inland shipping fleet is partly determined by the changing regulations.

The most important regulatory institution for inland navigation is the Central Commission for Navigation on the Rhine (CCNR), based in Strasbourg. The CCNR has been around for over 200 years, and the first regulations for inland navigation were introduced in 1868 with the Mannheim Act. The resultant 'Regulations for Vessels Investigation on the Rhine' was transferred in 2018 to the European Standard laying down Technical Requirements for Inland Navigation vessels (ES-TRIN).

This legislation is constantly being modernised and adapted to the latest technical developments. For example, the emission requirements per 1 January 2019 (< 300kW) and 1 January 2020 (> 300kW) have been tightened for new engines to be installed. In addition, technical regulations for electrical propulsion have now been included and a start has been made in drawing up regulations for the use of hydrogen fuel cells. Reducing noise

Figure 6: The inland tanker *Dortsman*, 135 x 17.5 x 6.20m, was delivered last year. Source: Rensen Driessen Shipbuilding B.V

produced by ships is also an item on the agenda for the coming years.

The ADN Administrative Committee, with the ADN Safety Committee in Geneva as its executive body, is responsible for drawing up requirements for the transport of dangerous goods. The decision taken in the 1990s to phase out the single-hull tankers has made an important contribution to the renewal of the tanker fleet.

In 2015, the requirement to have a loading computer on board double-hull vessels was introduced. The accompanying update of the leakage stability calculations has resulted in adjustments to existing ships and impacted the design of new tankers.

The ADN is also constantly being modernised and the latest developments in this regard concern the stricter requirements in the field of explosion safety. These requirements came into effect on 1 January 2019 and have had an impact on the design of both dry cargo ships and tankers. *NA*

About the author

Bas Joormann, Ing., is Lloyd's Register's Principal Specialist on inland shipping in Europe.

Special thanks to Dr Norbert Kriede, Central Commission for Navigation on the Rhine, for providing the graph data.

Time to rethink design of inland vessels?

A change in design of inland vessels could be on the horizon as retreating water levels slowdown production, write Igor Bačkalov and Dejan Radojčić of the University of Belgrade's Department of Naval Architecture

The third quarter of 2018 may have been the turning point in design of European inland vessels, or at least signified the start of a thorough reconsideration of the present inland self-propelled cargo vessel design.

According to business media reports [1] low water levels on the Rhine in the third quarter of 2018 contributed considerably to a 1.7% slowdown of industrial production in Germany in the same period. The data provided by the Central Commission for Navigation on the Rhine (CCNR) also emphasises the impact of insufficient water depth on economics. For instance, in the third quarter of 2018, the freight rates in tanker shipping on the Rhine were up to 3.5 times higher than in the previous three quarters [2].

Due to low water levels in August and September 2018, the navigation on the Rhine was suspended for two periods of 30 and 15 days, respectively. Is it possible to consider such weather conditions as an extreme and therefore a rare, statistically insignificant event?

Contemporary research on the impacts of climate change on transport warns against such conclusions, as the frequency of low water periods on some of the major inland waterways could even increase in the future. Hence, it seems that the influence of long-lasting periods of extreme drought on inland navigation cannot be disregarded and should be taken into account when designing a vessel.

The modernisation of inland vessels in Europe mainly concerns the innovative solutions aimed at improvement of propulsive efficiency (e.g. project MoVe-IT!), the use of alternative fuels, the use of telematics and other means of assistance in operation (such as CoVadem platform) and, as of recently, the promising opportunities for introduction of autonomous shipping on inland waterways (e.g. project NOVIMAR).

The main particulars of the new-built vessels (which are typically divided in CEMT classes), however, do not change significantly. It could be argued that the vessels are considered to be already optimised in this respect, as the choice of the main dimensions is decisively affected by the waterway constraints, including the height of bridges (affecting vessel air draught), the length and breadth of locks (affecting vessel lenght and beam) and the fairway depth (affecting vessel draught).

Yet studies indicate that a modification of main dimensions in comparison to the standard ones could improve vessel performance.

It is well-known that the proper selection of main dimensions is by far the most important aspect of ship design. Concerning inland vessels, the most sensitive parameter is the design draught, which is to be selected within narrow boundaries. The draught should be sufficiently large to provide for adequate cargo carrying capacity and simultaneously small enough to account for the water depth restrictions.

Typically, during the low-water level seasons, the ships sail in an inefficient, low draught regime prompting increased freight rates. If low-water periods become extended and/or more frequent, it is reasonable to assume that a more sustainable, long-term solution would be sought. Could this solution be achieved by a novel approach to design of inland vessels?

Optimised vessels for the Danube – and beyond

The state of inland navigation in the world varies from one region to another. But beyond any doubt, the Rhine basin could be considered as the most developed region in this respect in Europe. Therefore, there is a tendency (and a temptation) to directly apply the Rhine experiences in design and operation of inland vessels elsewhere in Europe.

The process of harmonising technical regulations for inland vessels in Europe follows a similar path. For the most part, the ES-TRIN (European Standard laying down Technical Requirements for Inland Navigation vessels) contains rules laid down by the CCNR.

Nevertheless, inland waterways may differ considerably with respect to navigational conditions. These include fairway constraints (shallow and restricted waters, presence of locks, river bends, etc.) and prevailing weather conditions (high and low water levels, presence of ice, strong gusting winds, etc.).

Perhaps the most prominent difference between the Rhine and the Danube is the water depth. The Danube is characterised by the shallow-water sectors on the Upper Danube and, in particular, on the Lower Danube.

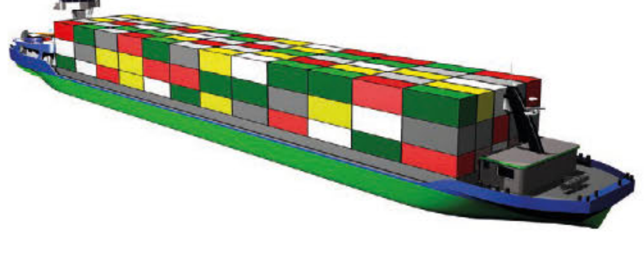


Figure 1. Novel shallow-draught container vessel for the Danube, from (4)

The design draught of the so-called Large Rhine vessels (CEMT class Va, length L = 110m, beam B = 11.4m), which form the backbone of the transport on the Rhine, is typically well over 3m. On the other hand, the inventory of the bottlenecks on the Danube reveals that 2.5m draught – targeted by international agreements as the minimum that ought to be possible for most of the year – cannot be achieved in 'dry seasons', which could last for weeks or even months.

With these specific navigation conditions on the Danube in mind, the Department of Naval Architecture (Faculty of Mechanical Engineering) at the University of Belgrade conducted several studies on the design of (extremely) shallow-draught self-propelled cargo vessels. The goal of these studies was to investigate the feasibility of a shallow-draught alternative to the Large Rhine vessels, that is, a design which would fit into CEMT class Va but would enable navigation throughout the year.

For instance, in one study [3] a novel container vessel design was proposed. The length of the vessel was L = 104m while the beam was B = 11.65m, in order to accommodate four rows of both ISO and pallet-wide containers in the hold, while still being able to sail into the locks with a 12m wide chamber. Special attention was paid to low-draught performance.

Consequently, the proposed concept should be able to operate cost-effectively at both low draught of around 1.7m and design draught of up to 2.5m. To enable this, a ship form optimised for low draught navigation with relatively small propellers in nozzles of 1.35m was adopted.

Another container ship concept, the so-called X-Type (see Figure 1) featuring a vessel of approximately the same length (L = 103.8m) was presented [4]; however, the beam was increased to B = 13.9m as to introduce the fifth container row, while the draught was further decreased to d = 2.3m.

On paper [4], these two vessels were compared to other more conventional designs with deeper draughts. The comparisons were made with respect to the maximal annual cargo-carrying capacity, the maximal ship speed in limited water depth (taking into account the possible squat) and energy efficiency with respect to number of TEUs carried in limited water depth.

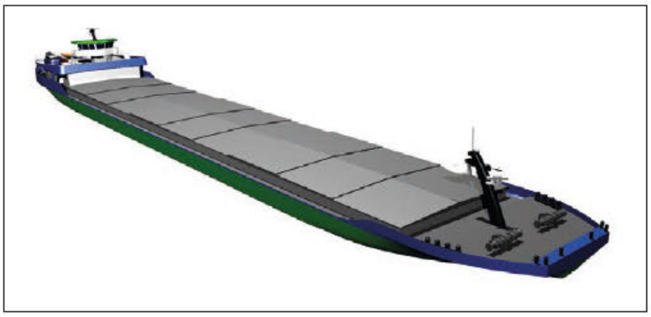


Figure 2. Novel shallow-draught bulk carrier for the Danube, from (5)

The study [5] introduced the so-called E-Type vessel: a bulk carrier for the Danube with an extremely shallow design draught, d = 2m (Figure 2). In order to compensate for the cargo capacity lost due to the low draught, the beam was increased to B = 15m. The length of the vessel was L = 103.8m. Again, the comparisons were made with the standard deep-draught vessels of the same class by calculating the transport costs for a range of water depths (see Figure 3).

Regardless of the criterion used, the conclusions are unanimous: if the water is sufficiently deep, the shallow-draught vessels may not be as efficient as the deep-draught ones.

Yet in limited water depth conditions (that is in hw ≤ 3.5m), the shallow-draught vessels perform better and may attain higher speeds as well as lower transport costs. Perhaps most importantly, being climate change-resilient and less dependent on weather phenomena, they could provide continuous service throughout the year and thus improve the reliability of inland navigation.

The shipowners, however, are yet to embrace such innovations in design. *NA*

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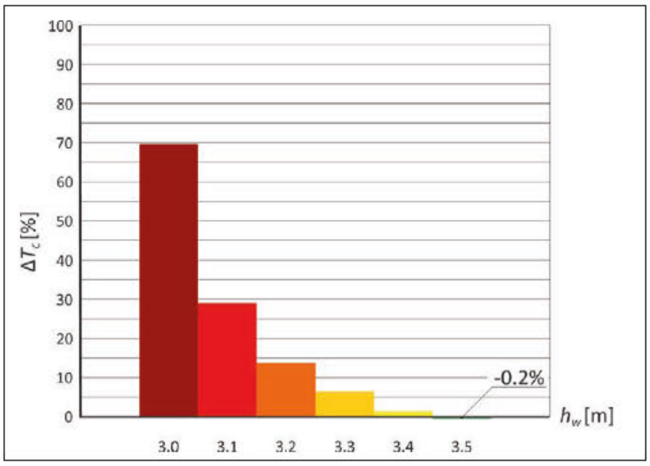


Figure 3. Average increase of transport costs of the standard vessel at 2.8m draught, in comparison to the transport costs of the shallow-draught E-Type vessel, in limited water depth

The sun sets on Blue INNOship

Denmark's largest ever maritime innovation initiative has ended its four-year duration on a high note, says the partnership's manager

When it was launched, the stated objective of Blue INNOship was to develop a green innovation model for the Danish maritime industry that would foster employment and economic growth. Such noble aims are nothing unusual, but what has really been achieved?

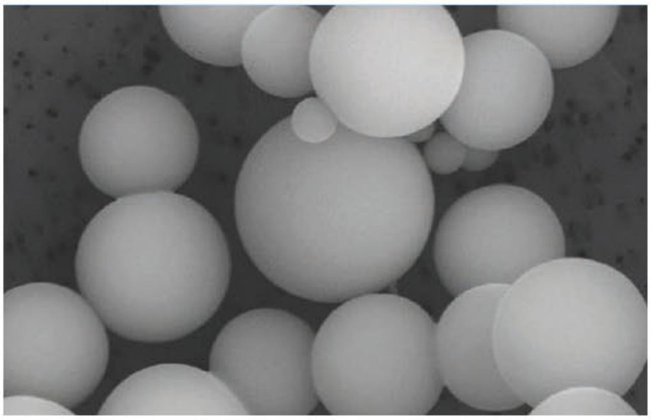
"Overall Blue INNOship performed extremely well compared to what we had expected," reflects Magnus Gary, who oversaw the collaboration between more than 40 project partners on 16 different projects, with funding in part from the Danish Maritime Fund, Innovation Fund Denmark and D/S Orient's Fund. "That was both because we got better results than we had anticipated but also the whole collaborative process between the partners."

In March, Blue INNOship held its final conference at the Technical University of Denmark (DTU) in Copenhagen, with many of the project partners fulsome in their praise of the efficiency with which the project was managed. Gary believes a critical part of that was ensuring their time was being used productively. "It was very important that nobody ever felt a report they wrote wasn't going to be used," he says.

As previously covered in *The Naval Architect* (see April 2017), the Blue INNOShip projects were divided into a number of sub-categories covering ship and propeller design, performance monitoring, alternative fuels, emission reduction and servitization. They ranged from modest feasibility studies to concept designs, but for the most part emphasis has been on pragmatic research.

For example, a collaborative project led by engineering firm Eltronic and MAN Energy Solutions, successfully developed a gas valve train that would make it possible to increase the pressure of gas injected to two-stroke engines from 30 MPa to 60 MPa. "Both companies are very happy and have integrated it into their commercial products. Nobody is likely to ask for a 600bar gas engine right now, but they've pushed the limit for what was possible."

While around 30% of the partners are planning to market products based on research from Blue INNOship, a number yielded useful results without necessarily being ready for commercial exploitation. Another project involving MAN, this time working with DTU and Danish Technological Institute (DTI), found through combustion modelling that it was possible to reduce unburned methane in a gas engine by 40%. Albeit, the partners have yet to find a shipowner willing to participate in practical application.



A partnership between Hempel and DTI to encapsulate coating biocides didn't achieve the desired results, but has given rise to further collaboration

As an initiative partly funded by Danish taxpayers, Gary feels it was important to deliver meaningful results even if not entirely successful. A project between coating manufacturer Hempel and DTI hoped to achieve a more controlled release rate for biocides in hull coatings by encapsulating it in silica, thereby extending the coating's longevity. When the initial technology approach failed, enough time remained to try two further approaches. Although these too have been unsuccessful it's formed the basis for further collaboration between the two partners. "Even though they haven't reached results they've proven ways that don't work, like Thomas Edison and his 10,000 ways of not making a light bulb," says Gary.

By contrast, there is one project in particular that he points to as a resounding success: the Vessel Performance Decision Support tool. The project brought together ship operators TORM and Lauritzen with analysis specialists Vessel Performance Solutions for the development of a performance management platform. "It was apparent halfway through that they'd hit a goldmine. The analysis engine allowed the shipowners to save up to DKK100 million (US$15 million) a year in bunkering costs, which was also more than 100 tonnes of CO_2 per year."

Perhaps the most ambitious project was the Trailer CAT, initiated by maritime consultant Claus Kruse and naval architects OSK-Shiptech, which explored the viability of a catamaran-configured ro-ro designed for large-volume transportation of unaccompanied road trailers and other rolling cargo. While it could potentially mean significant cost and CO_2 reductions, it would require fundamental changes to logistics infrastructure, not to mention the cultural challenges of dealing with the labour unions on the proposed trade route between the US and Mexico. "In terms of the project goal they've reached it, done the design and analysis, and made a good business feasibility case. But for now it's just a nice paper study," says Gary.

In conclusion, Gary admits that while overall Blue INNOship has been an exercise in the benefits of collaboration, even more could have been achieved if additional partners were willing to think outside the box and learn more from each other. "A chemical engineer and a mechanical engineer don't think in the same way, but by applying other people's thinking patterns you can learn something new." *NA*

ShippingLab begins its unmanned journey

Blue Denmark's latest initiative is an innovation partnership that aims to lay the groundwork for Denmark's first autonomous, zero-emission ship

By its own admission, Denmark is a little bit behind the frontrunners when it comes to research into autonomous vessels. While its neighbours, Norway and Finland, have established test bed facilities and demonstration projects, the most notable Danish accomplishment has been the demonstration of a remote tug operation conducted by Switzer in Copenhagen harbour in 2017.

However, the official launch in March this year of ShippingLab – a non-profit three-year project under the government's Blue Denmark banner – hopes to redress the balance. It will bring together nearly 30 industry partners with the goal of establishing Denmark as one of the drivers of smart shipping and create the country's first autonomous, environmentally friendly ship.

"It's not that we're going to build one specific ship, but also the technological development that will feed into that," explains Magnus Gary, who, fresh from overseeing the Blue INNOship partnership, will serve as ShippingLab's project director. "What's important for ShippingLab is that the technologies are scalable in reach and size. That means both the physical capacity of the ships and boats themselves and the capacity of the technology to, for example, increase the distance of zero-emission operation areas."

The overall objective is to reach the point where a Danish vessel is capable of unmanned operation. In addition, one of ShippingLab's four 'work packages' will focus on developing novel methods and algorithms that can be integrated with existing navigational technologies. There are also a number of defined objectives such as: to demonstrate one-man operation of a ferry with a temporarily unmanned bridge and to demonstrate unmanned operation of a water bus with built-in provision for remote control as a safety back-up.

The automation package will be co-ordinated by the Technical University of Denmark, with other participants including DFDS, Danelec Marine, MAN Energy Solutions and Wärtsilä Lyngsø Marine. Gary points out that the emphasis is not on competing with their Scandinavian neighbours but on identifying those areas where it makes economic sense for Denmark to become involved in autonomy. The aim is to carve out the country's own niche and eventually adapt ShippingLab's research into commercial products.

Magnus Gary will act as project director, following his previous coordination of Blue INNOship

However, the final integration will be open source. "It's important to stress that, unlike Blue INNOship, ShippingLab will focus on the pre-competitive stage of technological development. Most vendors will try and build walls around a product and charge a fee to work with the data. This way we hope technology providers will think more creatively about how to monetise it. From a societal perspective it makes sense to have open standards, as the Internet of Things is never going to work if the different products can't talk to each other."

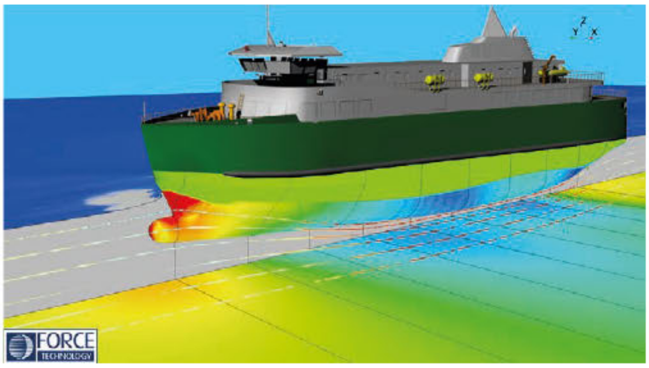
There will also be a complementary technology work package focused on digitisation, which will look at vessel modelling and developing more precise estimates of the effects of the environment on vessel performance. Additionally, it will explore digital twinning through high-frequency ship-to-shore data, with the vision of making Denmark a centre of excellence for performance management. As with autonomy, there will be a strong emphasis on shared models and data as well as defining the methods of interface between different components.

Another separate package will concentrate on decarbonisation. While Gary admits it hasn't yet settled upon specific objectives, its goals are loosely defined as demonstrating the viability of zero-emission power supplies during port operations or operation in other defined areas. A probable area of investigation is likely to be hybrid-based systems involving fuel cells and batteries, but it will also explore a broader roadmap to a green transition. "My personal hope is we could look into alternative solutions. In terms of IMO's 2050 goals we know we'll need another kind of fuel than we have today but we don't know what it will be. So we will need an intermediary fuel that's not too costly to develop and has the ability to bring us closer if not all the way to the 2050 target," he says.

ShippingLab is still in its infancy; its first step is to minimise overlap between different branches of research and work being conducted outside ShippingLab. "It's about laying bricks for the future. Whatever technologies we end up looking into we're going to take it as far as we can over the three years and that's it. Other countries and collaborations will lay bricks of their own. We are going to play out part in this challenge but we're not going to solve it all by ourselves." *NA*

Force Technology launches virtual laboratory

Funded by the Danish Ministry of Higher Education and Science, the two-year project aims to raise the bar for design processes



The virtual lab will facilitate easier testing of different configurations for ship manoeuvrability

Denmark's Force Technology has long been recognised as one of the world's leading model test facilities. Although experiment-based services remain the backbone of its business, the company is turning its attentions towards more holistic solutions in line with today's wider needs.

As one of seven Danish government-approved research and technology organisations – the GTS network – Force is operated as a commercial business but with non-profit goals, partly with the aim of providing a conduit between academic research and its application in the real world. The GTS organisations are also able to apply for public project funds for R&D into future market needs. The project proposals are posted online and the public is invited to comment upon them or make suggestions as to how they might be done differently.

In February, Force announced that it had won a grant totalling DKK12.1 million (US$1.6 million) for three maritime projects that will take place over 2019-2020. One of these is to establish what is described as a 'Virtual hydro- and aerodynamic laboratory and knowledge base', with the aim of shifting Force from its role as a pure data supplier towards providing an enhanced suite of services, as needed particularly by small to medium sized companies.

Claus Daniel Simonsen, head of Force Technology's Hydro- and Aerodynamics department, explains: "We want to move towards virtual testing and machine learning applications that can be as equally trusted as our experimental test facilities. The basic idea is to go into more virtual assignments, which of course is very broad, but this project is focused on some subsets of our activities that we want to emphasise over the coming period."

The project will initially concentrate on four areas of Force Technology's current research, which could benefit from a more iterative design approach. Two of these – on design lifecycle evaluation and computational fluid dynamics (CFD) based ship manoeuvrability simulation (see also p.27) – are marine focused, while the other two relate to civil engineering projects.

Typically, model testing for ships and offshore structures takes place relatively late in the design phase, due to the expense and time it takes to build a physical model. By that point, it's usually no longer practical to make anything more than a few minor adjustments. A clear benefit to virtual testing is the ability to support decisions much earlier in the design phase, allowing for a more agile design process that switches easily between ideas and evaluations while working towards the final design.

As such, it is hoped the virtual lab can enhance Force's capabilities as a data-based consultancy, something broadly in line with the Danish government's Maritime Denmark report (see *The Naval Architect*, April 2018), which identified digitisation as critical to keeping Denmark at the forefront of the maritime sector.

"It's what people expect from a company like ours that we're at the forefront of using and applying new technologies to support the industry and thereby form the bridge between research and application," says Simonsen. "But it's also to help those companies who aren't big enough to work with the advanced technologies by themselves."

The main markets are expected to be shipowners, operators and design consultants. "It could be related to optimisation for new or existing vessels where it is desired to evaluate different aspects, such as how different components might be used in configuration. For example, if you wanted to see the effects on maneuverability or fuel consumption of changing the rudder configuration, or modifying the hull shape," says Simonsen.

Another might be, in terms of fuel consumption, if a shipowner or designers wanted to evaluate the impact of a different propulsion system to assess its efficiency.

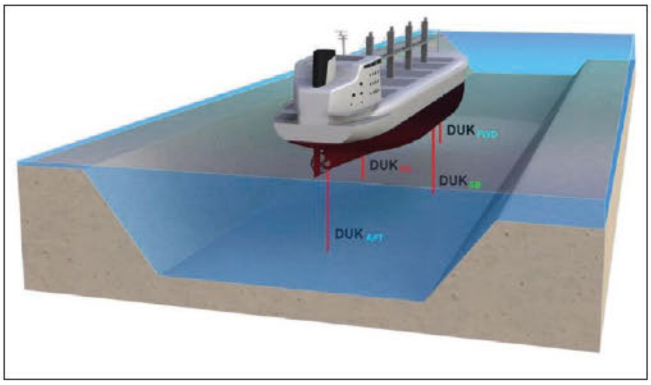
Simonsen explains the purpose is to cover all three aspects of design and development: environmental questions, safety and saving money. One particular area of importance will be issues concerning the management of the ship across its lifecycle.

"Traditionally you design for one specific operational purpose, but here we're trying to cover more broadly with these services that give you a more complete picture of the ship's lifecycle. That consideration of the ship's entire lifespan also lines up much more with the digital twin."

For Force Technology this supports the strategic focus on virtual services and a broader involvement in the design work. "We're from the tradition where we're asked to measure and test at few discrete points, rarely the entire operation, so in that sense it's a step up." *NA*

Force Technology's maritime simulator to offer new depths of analysis in shallow waterways

The Danish organisation's latest project announcements include improved modelling of ship hydrodynamics for accurate manoeuvring in tight situations



Force Technology's simulators are used for both training and analysis

Force Technology has been complementing its towing tank and wind tunnel facilities with mathematical modelling services for 40 years. By the 1990s the synergy of these capabilities – taking measurements of both external forces and internal forces – made it possible to offer simulation services for training and analysis purposes. However, performing calculations on hullform in a real-time simulation has long been hampered by the computational power required to perform this accurately.

But advances in computing over the past decade, notably the opportunity to exploit the processing power of graphics cards originally developed for gaming, means that it's now possible to calculate forces on a ship based on a grid model of the vessel and perform massive parallel computations. Now, as part of a new two-year innovation project funded by the Danish Ministry of Education and Research, Force Technology is set to bring these gains into its simulation platforms with the announcement of a ship hydrodynamics model. The model will make it possible to obtain far more accurate simulations of the wave and flow conditions around the ship in shallow waters, ports and channels to obtain the correct ship response.

According to Jens Erik Bay, senior project manager at Force Technology, the project was set-up in response to the growing demand from shipowners and port operators for more precise data, particularly as ships grow larger and navigating them into confined waterways becomes more hazardous. Force Technology is regularly requested to perform simulations to ascertain the conditions under which a ship can be brought safely into port and advise on changes needed to the design, even at an early stage in the design process. Simulators are also deployed for ships that have already been built, for example to familiarise marine pilots with a new ship type ahead of its delivery.

"The interesting thing about this development project is the calculations on the actual shape of the ship, enabling us to analyse its manoeuvring characteristics as it approaches a port or is passing through a channel. The method we use today is based on coefficient tables and formulae that are a very good but simplified version of real-life. With this project we get a huge increase in accuracy and get much closer to reality", Bay says.

When a ship enters a confined waterway, it is subject to a variety of challenging hydrodynamic effects including: the suction caused by shallow and narrow water channels, and the increased pitching and rolling caused by waves and swell. A particular issue for today's larger ships is under keel clearance (UKC), which can sometimes require millions of dollars of dredging. Therefore, anything other than an optimal solution can have huge cost implications.

Ole Lindberg, who serves as the project's manager, says that the initiative is part of a trend away from physical towing tank and wind tunnel experiments towards computer calculations. "What we're aiming at is calculation of the flow of the water around the ships (in harbours and channels), as we're simulating in real-time.

"For example, if you want to determine the interaction forces between a tanker and a tug at model scale in the towing tank, we can only do it in a finite number of experiments and then use this data to estimate the forces in the simulator. But, of course, that's limited to specific hull shapes and to do it accurately with other ships you would need to make more physical models and do more experiments, which is an expensive process."

From the customer perspective Force Technology would likely be able to offer clients more value for their money as there will be need for fewer physical tests. This is particularly beneficial for the small and medium-sized Danish companies that Force is focused on supporting, although it has clients as far afield as Australia.

The new hydrodynamic model will be integrated into Force Technology's existing SimFlex software, which is used in its DanSim training centre in Lyngby, near Copenhagen and in their training centre in Singapore. However, Bay stresses that it by no means implies towing tank tests are in any immediate danger of becoming obsolete. "Most shipowners, designers and shipyards will, for example, keep using them to figure out precise resistance and how much engine power is needed because it's so important for a ship's economy. So, tank tests will still be done, but this will allow us to skip part of the normal equation for putting together a mathematical model." *NA*

What should shipbuilding expect from the CAD/CAM systems of the future?

As shipyards and engineering offices embrace the Industry 4.0 revolution, it's important to select CAD/CAM/CAE systems with certain key attributes, write Arturo Benayas-Ayuso and Rodrigo Pérez Fernández of the Universidad Politécnica de Madrid (UPM), Spain

The Industry 4.0 revolution covers a vast array of interconnected and interlaced technologies, each of which is a unique discipline, but should be implemented as a whole integrated development in each industrial field. This is particularly so for Computer Aided Design, Manufacturing & Engineering (CAD/CAM/CAE) systems, from now on referred to simply as CAD, development industry.

The limits and parameters of each technology are often not clearly distinguished from those of neighbouring technologies. For example, Augmented Reality, Virtual Reality and Mixed Reality are closely related to the Digital Twin and interlaced with the Big Data which is generated by the CAD tools and other solutions, which applies some cloud/edge/fog computing to this data to create a fusion of finite state machines and Artificial Intelligence (AI) cognitive processes.

To smoothly perform all this computing requires a network that supports different connections for special devices (Internet of Things – IoT) that can access the data, creating and modifying it into a new layer that enhances the basic information layer created by the shipyard's CAD system.

This network should be cyber-secured but open to allow distributed work, and step controlled in a manner that records any modification of each working step done in an open, transparent, trusted and non-modifiable working method for all actors involved in process (e.g. the shipyard, engineering offices, classification society and shipowner). This is one possible application for Blockchain-based communication.

Results of the design should be easily integrated with future building operations, like 3D printing and generating printing orders directly from the CAD model. While the shipbuilding phases focus upon the design and construction an integrated Industry 4.0 CAD system should also factor in the vessel's future operation and maintenance.

Fig.1 Related Industry 4.0 Technologies in a Shipbuilding CAD environment

When a ship comes for repair work, sometimes the model is not available for this operation of maintenance and replicating the entire engine room or any other localised area of the ship in the CAD System can be a nightmare. This is unless the CAD system has an AI processing toolkit which, from a cloud of points, can recreate CAD equivalent items that can be converted with minor user intervention (and decreasingly so as the AI learns) into a CAD integrated and full modifiable design.

Figure 1 illustrates the Industry 4.0 technologies which can be applied to a CAD System as part of an integrated solution in an evolutive design process.

IoT sensors and tagging

To help integrate the production process into the design phase, the CAD System must be oriented to be fed by sensors in the shipyard environment.

Sensors require some active elements – item tags – in order to extract useful information for the CAD and other tools. The CAD system has included in all its items enough information, in the form of attributes, to generate an accurate and unique Quick Response Code (QR) tag or, in an advanced environment, a fully functional Radio Frequency IDentification (RFID) tag.

These can include not only an identification, but also a set of basic parameters. Based on these tags, distributed IoT sensors can inform the system, through reading a QR tag or a passive RFID tag, about parts that have reached a production maturity state which avoids CAD user modifications, applying a locking method to them in the system. [1]

RFID tags are not merely a simple identification method, but depending on the inner capacity in bytes, CAD tools can add other information, such as the required installation or operation basic default set of parameters. In this case, an engine room operator does not require connection to the onboard catalogue for each installed part to configure the system, as this information is saved in the RFID tag attached to the element. These high byte capacity tags may be reserved for critical or main equipment items.

If the RFID tags include some sensor capabilities, this information can be used in the ship's operation phase to control the state of the tagged parts. Sensors from the shipyard and the ship produce a lot of data, which must be processed, arranged and discarded. [2]

Artificial Intelligence

Control systems in the ship can include some AI predictive processes integrated into the bridge's overall control system, which helps to deduce the consequences of maintenance operations, by doing them in the correct time, delaying or skipping them. [2]

This procedure can be applied using edge/fog computing methods within the ship's inner communication network, avoiding the massive download of operations data upon arrival at port. During navigation, ship-to-shore data transfer should only be applied to critical operations.

Navigational data can also be useful during design and production phases, to correct some processes in order to obtain more efficient systems and designs. This is only possible by applying AI process to this data, classifying, processing and collecting some results. Such a working methodology requires close collaboration between shipowner and shipbuilder, yet can be deeply profitable for both actors.

AI processes based on navigational data, in the multi-boat paradigm, can obtain information to improve design and production processes, which may be applied either to the current series, an evolved variant of this vessel type or similar. The ship's operation phase is not the only one which produces a set of Big Data to be processed by an AI system. In the production phase, some calculations can be done in the workshops or even delegated as part of distributed cloud system. This data, in CAD AI tools, can be classified generating working sequences, automatic checks, and automatic design processes.

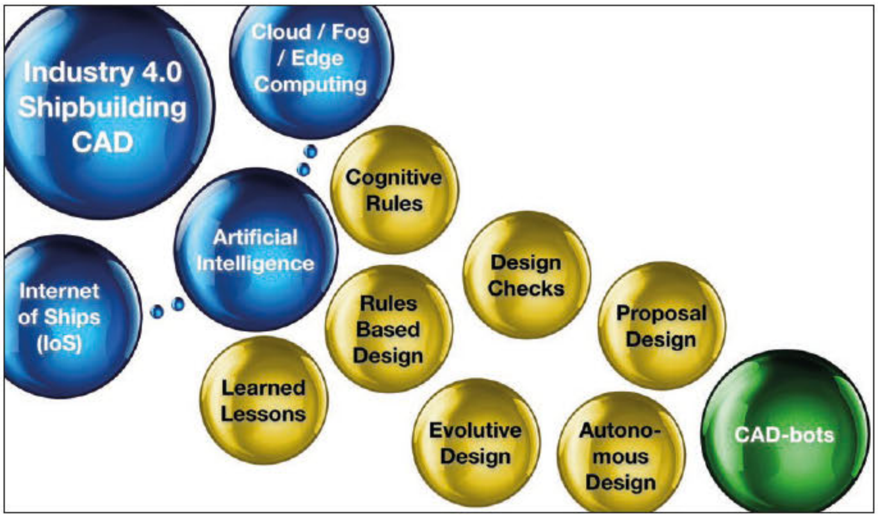


Fig.2 AI Evolution in the Shipbuilding CAD World

More specifically for the designer, sometimes the tight schedule, or for the start-stop working requirements of the design office, can mean there's little time for the principal task: creating fully effective designs, which requires concentration and calm. This problem can be solved by AI, which can apply some design rules, highlighting a variety of effective solutions, while delegating the final decision to the designer and eliminating a large number of previous solutions which have already shown some problems.

Some sceptics may believe that AI will remove the need for designers. However, in reality, it will enhance the capabilities of designers, making their work less stressful and more efficient. All available AI processes which can be applied in a CAD system to help designers are represented in Figure 2.

First level AI CAD tools

AI applied to a CAD system should be based on the standard ways of controlling a design:

- Rules Based Design
- Lessons Learned
- Cognitive Rules

Rules based design is the shipyard's standard book of rules. These rules are the basis of any shipyard design and are the first to be learned by our AI system. To improve it other technologies such as cognitive AI, which is the basis of natural language processing in an AI solution, can also be applied. This cognitive AI can be run over the shipyard's standard book of rules and, with some user help, through application of the rules gradually improve the AI tool's understanding. All AI solutions require a specific time to learn the correct ways to apply the set of rules.

The next step is to add the learned lessons to our AI solution, creating a mixed ecosystem of rules to be applied to the current design process.

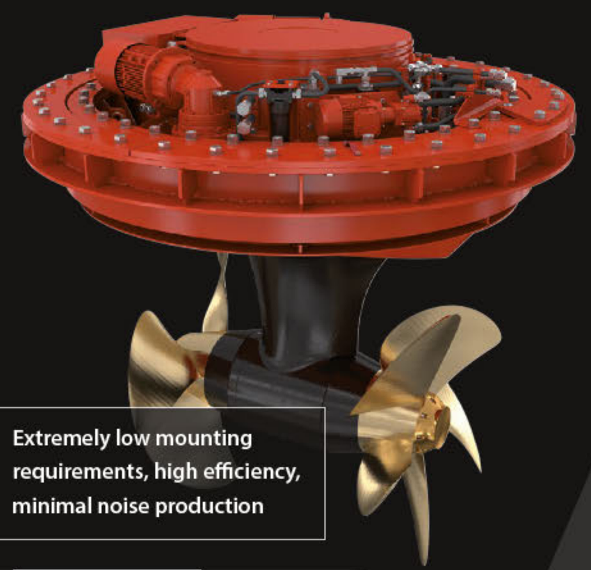
The last step, but no less important, is the cognitive rules. These rules are deduced from both the current design and from production error input in the CAD system, like design incidences.

Second level AI CAD tools

With all first levels fulfilled, second level steps can then be applied:

- Design checks
- Evolutive design

The first improvement applied in the CAD AI is to unobtrusively assist users with the design, by offering a list of design rule application failures to the current



work. This list, if it is based on evolutive design, can not only fix design issues but also offer an improved solution to the user.

The solutions offered are based on the experience accumulated from similar issues found in the previously applied design improvements. These steps generate learned lessons input in the AI system. Second level tools require a high level of design knowledge to be trained faster, like a design checker role.

Third level AI CAD tools

Once the previous two levels have accomplished their 'training', a third level of tools arise:

- Proposal design
- Autonomous design

Proposal design is one of the most required tools in a natural language interchange: e.g.:"Please, which are the best ways to connect this equipment and that pump?". Based on the cognitive learning process of the CAD AI tools, the answer can be interpreted in machine language as to route some pipe lines which connect both items and let me select the better one on my design criteria.

This last step also generates learned lessons input in the AI system. Autonomous design requires a large number of approvals of the previous questions, and based on these and the Piping & Instrumentation (P&I) diagrams, can look for the best location for equipment items in the ship, as well as creating a piping solution of the system. This step generates cognitive rules input in the AI system.

These third level tools require months, or even years, of training in the CAD AI tools, creating CAD-bots, autonomous designers which, based on a simple input such as P&I diagrams, can recreate a 3D accurate design. CAD-bots accomplish the most when not all design rules are applied.

AI CAD-bots

These CAD-bots are AI augmented cognitive bots which can automatically perform some design parts based on the lessons learned and cognitive rules, but always fulfilling the complete list of the shipyard standards book of rules.

At this time, AI tools, represented by the CAD-bots can only highlight the designer rules which have a conflict and reapply approved rules to the previous design, reducing effort. CAD-bots can design and offer users a set of the most efficient solutions, helping in some complex design processes, like the study of the impact of deep design modifications or even classification rule changes, augmenting user capabilities. By no means are CAD-bots the solution to all design problems, but are orientated to do the most repetitive tasks and help with some design corrections.

Cybersecurity and Blockchain

Cloud computing requires transfer of sensitive data through an external network to our system, where it is processed and the response, which can include even more delicate data, used in the client system.

Some crypto processes are required to hide this data to curious, or even malicious, people. These processes require

> "CAD-bots can design and offer users a set of the most efficient solutions"

a secured channel, to double-check and validate the information and some special operations all developed in the cybersecurity paradigms.

Based on those paradigms, in 2009, Blockchain methods – a form of timestamped cryptography first conceived in 1991 – were applied to cryptocurrency, opening the doors to a new interchange-trusted world which eliminates the need for a bank intermediary in monetary transactions. [3] This cybersecurity paradigm represents a new tool for distributed and shared work in all industries, but particularly so for shipbuilding, and the even greater security requirements of its sibling, naval shipbuilding.

Blockchain technology offers a secure channel which requires an invitation, a special program that knows all connection data, and where every operation performed is validated for all available connections and saved in a non-modifiable way. Additionally, all the agents have a full copy of these operations, generating a trusted work methodology. A CAD tool that includes the possibility of a Blockchain creation per each distributed work, and which locks items based on the assignation to a Blockchain operation can be included in the new era of Industry 4.0.

Conclusions

Each technology reveals a set of limits which cannot be clearly distinguished from its neighbouring technology. IoT generates one of the largest sources of data, which can be consumed by the AI and the CAD to help during the design process used in building or repair and maintenance.

In conclusion, we would like to leave a final reflection for the reader's consideration: for CAD software to fully succeed it must be able to achieve with AI that which the human brain can accomplish. *NA*

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Heavy lifting takes the strain on Clyde patrol ship launching

Henry Abram & Sons deploys an innovative float-off launching procedure for river patrol vessels, allowing them to enter the water with a greater level of outfitting than ever before, writes Jonathan Fettis

For thousands of years the most common means of launching ships has been dynamically, due to the simple infrastructure required: a sloping foreshore that extends into the water. Even today, large vessels are regularly launched by fairly rudimentary means, such as airbags.

Other modern yards employ direct launches from very large drydock complexes, via bespoke pontoons or ship lifts, but all these require extensive infrastructure, that often costs many hundreds of millions of dollars.

The last warship to be dynamically launched on the Clyde by BAE Systems was the sixth and final Type 45 Destroyer, HMS *Duncan*, in 2010.

Figure 1: The launch of HMS *Duncan*. Credit: Picfair

However, Henry Abram & Sons Ltd has since provided engineering and operational expertise on the successful launches of four of the five new River Class Offshore Patrol Vessels (OPV) in Glasgow using semisubmersible barges.

In an industry consistently striving for improvements to safety, an alternative to dynamic launching, in certain situations, becomes highly appealing. The benefits of a controlled launch, such as that from a dry or floating dock, are well understood and revolve around some or all of the following:

- Increased outfit opportunities
- Reduction in temporary steelwork or hull attachments (e.g. drag chain anchor points or fore poppets)
- Reduced need for post-launch drydocking (for reasons such as the removal of launch aids)
- Increased safety
- Reduced risk

Where the infrastructure does not exist to launch vessels in this manner, it can be temporarily provided by equipment mobilised to the build yard. This can offer the benefits of a controlled launch without the large infrastructure investment required. However, the cost effectiveness of this must be carefully balanced out to ensure the gains in productivity and safety are enough to justify the additional outlay for equipment hire.

This process may seem relatively straightforward at first glance but in reality, such operations require extensive pre-planning and engineering works. This is to ensure the equipment, usually drawn from a wide range of suppliers, is compatible with the vessel being launched, the trailer or skidding arrangements used for loading, the semisubmersible barge, the shipyard load out quay and the nominated berth or open water location for the float-off operation.

Taking each of these in turn, the process can be grouped into three principle stages.

1) Weighing of ship

An accurate understanding of the ship's weight and centre of gravity (CoG) prior to float-off is imperative. A principal driver on the cost of a semisubmersible barge is often its maximum submerging depth, so we work to tight tolerances to ensure maximum cost effectiveness. Small changes to the CoG or the ship's float-off weight can have a significant impact on the final solution.

While a weight control team will usually track a ship's weight and CoG

Figure 2: Weighing of OPV. Credit: Malin Group

during the design, build and outfitting stages, discrepancies can creep in as the construction progresses. To mitigate any float-off risk, we advocate weighing the ship in the build hall or on the hard standing as close to the float-off date as possible.

2) Loading to semi-submersible barge

The load-out operation is the first critical site move, where the ship is loaded onto the semisubmersible barge using self-propelled modular transporters (SPMTs) and set down upon pre-positioned grillages. Sea-fastening works begin immediately and once everything is complete, including that the semisubmersible barge has been ballasted to a safe transit condition, it is then carefully manoeuvred to a float-off location.

3) Floating off

The semisubmersible barge is first ballasted down until the freeboard is reduced to approximately 1m. After all final checks are complete, the first in a series of carefully planned ballasting stages commences – incrementally filling ballast tanks against a pre-agreed plan.

The stability of the semisubmersible barge must be closely monitored throughout the operation. A minimal angle of heel must be maintained at all times, however, the semisubmersible barge's onboard ballast system can introduce slight deviations when multiple tanks are being filled simultaneously. Careful monitoring is required to make required adjustments in good time. Additionally, to ensure that no slippage between the ship and its transportation cradles occurs, we typically work to a maximum trim of 4^0 at any stage.

To minimise sudden changes in waterplane inertia, the aft end of the semisubmersible barge is typically submerged first, with stern trim assisting in maintaining inertia. This trim is maintained until the ship's hull starts to submerge, which will then contribute to the overall stability of the paired system. Once the aft end of the semisubmersible barge is below the waterline, and within close proximity of the seabed, the semisubmersible barge's forward tanks are filled to bring the bow down. This proximity to the seabed can offer a contingency in the event of unforeseen issues.

If the berth is tidal, tide heights and water depths must be monitored to ensure that the semisubmersible barge does not 'ground out' at any point during the operation. Contingency plans must also be in place to ensure that any tidal cuts or surges will not adversely affect the operation.

Figure 3: The load-out. Credit: Malin Group

Figure 4: The float-off pre-ballast/early stages. Credit: Malin Group

As the ship fully enters the water, an inspection team will usually perform an internal survey of the hull checking for water ingress. Should any issues be found the operation can be paused or reversed in a controlled and safe manner.

To understand when the ship is floating, buoys are tethered between the ship's hull and its transportation cradles. They are subsequently released to surface once the two are separated. Draughts continue to be closely monitored as the semisubmersible barge continues to submerge until the ship's draughts remain constant. At this stage the ship is then considered to be afloat.

The semisubmersible barge would then continue to submerge to attain the required clearance between the keel and the cradles. A final draught survey takes place after which the ship is handed over to a tow master and team of pilots who coordinate the tugs for tow-off and handover to the client.

Once the ship is clear, the semisubmersible barge can be resurfaced and readied for clean-up prior to its next operation. *NA*

About the author

Jonathan Fettis, is a Project Manager/Naval Architect at Henry Abrams & Sons Ltd (a Malin Group company).

Figure 5: Ship Floating. Credit: Malin Group

Optimising the process of shape optimisation using CFD

As the range, capability and accessibility of shape optimisation approaches using Computational Fluid Dynamics grows, knowing how best to exploit this technology offers real benefits to designers. In this abridged whitepaper, Dr. Stefan Harries of Friendship Systems explains the process

Optimisation is a human trait. People want to find a good, possibly the best solution under the given circumstances. Mathematically speaking it is minimising (or maximising) one or several objectives within a set of constraints.

Traditionally, an engineer would rightfully say that something was optimised once a handful of feasible options had been considered. However, for the last few years, formal optimisation algorithms, simulation codes and adequate computer power have become available, allowing the generation and assessment of potentially thousands of virtual prototypes. These resources are increasingly being utilised by designers, even in small companies.

Shape optimisation is conducted both for investigating new ideas and possibilities at the initial design stage and for fine-tuning of a given product at a later stage.

There are two major approaches to shape optimisation: parameter-based and parameter-free shape optimisation. Since the former is the more mature and popular approach, this paper will be devoted to it.

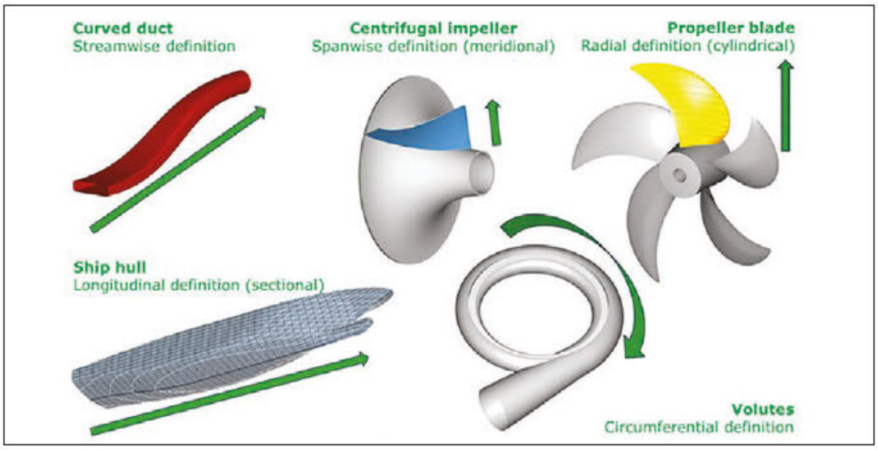

Fig. 1: Fully-parametric models with distinct directions of information (See also www.caeses.com/support/videos)

Parameter-based optimisation

Parametric modelling is the definition of a product (or the representation of system behaviour) by means of important descriptors. Today, most optimisation projects are parameter-based. The main reasons are that, firstly, design teams can easily interpret the meaning and impact of design parameters and, secondly, that multi-objective and multi-disciplinary optimisations can be carried out without any conceptual hurdle.

Many parametric models are developed within traditional CAD systems during the detailed design phase. These models are mainly intended for production and often contain details that complicate simulation (e.g. need for defeaturing). Thus, for shape optimisation using CFD, special parametric models are needed – so-called engineering models – which describe the product with as few significant parameters as possible, sometimes deliberately leaving out characteristics of lesser importance. These models address the concept and the preliminary design phases, focusing on simulation-ready CAD, and are realised within upfront CAD systems (see Fig.1). Two major traits of upfront CAD are distinguished: fully-parametric modeling and partially-parametric modelling (see [1] and [3]).

In fully-parametric modelling the entire shape is defined by means of parameters. A hierarchical model is created in which parameters describe all features of the envisioned product. Some parameters may be at a high level like the length, width and height of an object. Other parameters may determine details like an entrance angle at a particular location. Typically, many parameters are set relative to or as combinations of other parameters while some parameters may even be determined from additional analysis (e.g. formulas, background computation to reach a target value). A parametric model can be looked at as a system that takes parameters as input and produces a shape as an output. Any shape is realised from scratch and variants are brought about by simply changing the values of one or several inputs. For optimisation, fully-parametric modelling is very powerful since it enables both large changes in the early design phase and small adjustments later.

While many traditional high-end CAD systems support or even advocate fully-parametric modeling, very few systems were actually developed for the parametrics of flow-exposed shapes such as turbine blades, ship hulls and pump volutes. These shapes often feature one distinct path in which design information changes rather slowly while the building strategy orthogonal to that path stays pretty much the same (Fig.2). For instance, the blades of a propeller do not change significantly from hub to tip. Rather, the (cylindrical) profiles are nicely defined by the same parameter set with different values at each radius, comprising chord length, pitch angle, maximum thickness and camber etc.

Furthermore, the cross section of a volute does not really look that different from one angle to the next but rather evolves slowly in a circumferential direction with input such as the area-to-radius distribution.

This is illustrated in Fig.1, taking models created in CAESES system, which offers upfront CAD functionality dedicated to variable geometry as needed for optimisation. High-level geometric constraints can be readily incorporated while processing the shapes for maximum fairness. The blade of a turbine or a propeller may have to comply with a prescribed area distribution (e.g. for load considerations) while the hull of a ship or an offshore platform must meet a given displacement (e.g. to comply with weight estimates). Rather than treating these characteristics as output from the modelling process and subsequently adjusting geometry manually until all constraints are satisfied, many constraints can be directly incorporated into the model.

In partially-parametric modelling only the changes to an existing shape are defined by parameters while the baseline is taken as input. The baseline may stem from any previous modelling process. Prominent representatives of partially-parametric modelling are morphing, free-form deformation and shift transformation (e.g. shifts in coordinate direction, radial shifts).

In morphing, two or more objects that are topologically identical but geometrically different are combined. A well-known example is that of a cat and a dog which both feature two ears, two eyes and a snout (same topology) but, naturally, look quite different (different geometry). Mixing them with weights between zero and one creates anything from a pure cat to a pure dog with stages in between.

In free-form deformation, also known as box deformation, the geometry to be modified is enclosed by a regular grid of vertices. For all parts of the initial shape which lie within the box (or lattice) a coordinate triple can be determined. By moving any of the vertices the box changes its shape and, along with it, the baseline is transformed [5]. Here, the free coordinates of the box vertices serve as parameters. The technique is applicable to both surfaces and volumes, allowing box deformation to be exercised on a CFD mesh, too.

Shift transformations typically change any point in space by adding a certain displacement depending on the point's initial position. It can be applied to both continuous data (e.g. surface patches) and discrete data (e.g. points, offsets, tri-meshes as used for data exchange via STL). Fig.2 gives an example realised in CAESES, showing a vertical shift of a container ship's bulbous bow.

Partially-parametric models are usually quick and fairly easy to set up. When compared to fully-parametric models they typically contain less knowledge (intelligence) about the product. In general, it is more difficult to excite large modifications. After all, the new shapes are derived from the baseline and, thus, cannot look totally different.

The quality of a parametric model is decisive for the success of an optimisation. This is because understanding an n-dimensional design space spanned by n free variables of the model – namely the parameters that shall be consciously changed – is anything but trivial. As a rule of thumb a design team needs to study about n times n variants to gain a reasonable appreciation of system behavior. If there are only two free variables, four variants would give a first insight. From a mathematical point of view it would allow a bilinear approximation of system behaviour. If 10 free variables are involved, 100 variants ought to be evaluated. Working with many parameters or with parameters that are not really decisive quickly scales up the optimisation task beyond all practical resources.

In order to keep the number of free variables as low as possible from the start, a parametric model ideally needs to be developed that suits the design and optimisation task:

- All parameters are independent from each other
- All potential variants are intrinsically fair (i.e., free of any unwanted shape characteristics)
- Many (geometric) constraints are readily incorporated
- All variants are geometrically fit for simulation (i.e. free of gaps, folds, overlaps etc.)
- Shapes can be produced beyond the current engineering practice while avoiding unacceptable artifacts (well-balanced model). This is the most challenging to satisfy: by definition all parametric models confine the potential outcome. Nevertheless, the model must allow for new shapes.

Optimisation process

Parameter-based optimisation processes – though they might differ in scope and conduct depending on the teams, tools and tasks at hand – have a common set

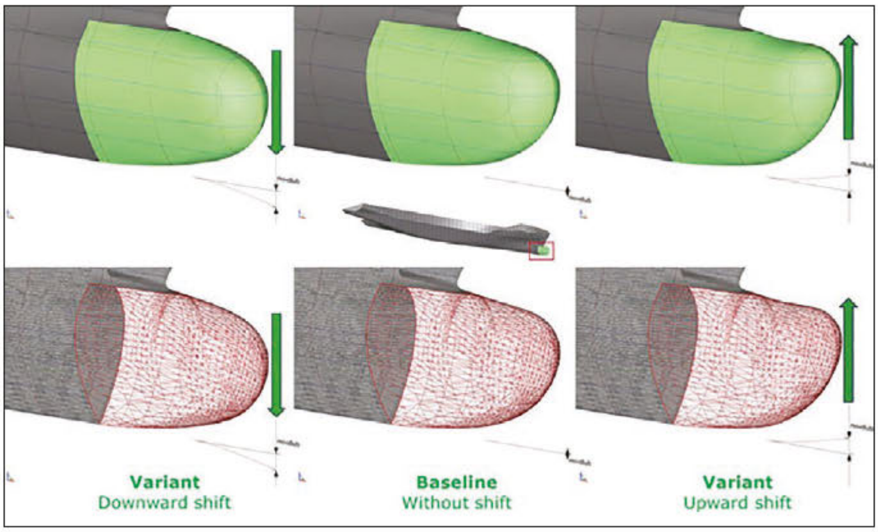

Fig. 2: Partially-parametric model for a downward vertical shift (left column), the baseline and an upward vertical shift (right column) applied to both B-spline surface patches and tri-meshes (center shows entire ship hull along with zoomed-in part (rectangle)

of elements and a typical course of action. At the very start the team needs to discuss and agree on objectives, free variables and constraints. Most projects then continue with a preparation phase during which a reasonable simulation set-up is established. Ideally, a grid variation study is undertaken to identify a resolution fine enough for acceptable accuracy, yet coarse enough for short turn-around time. Two distinct phases then often follow: exploration and exploitation.

During the exploration phase the design space is scanned with the aim of identifying promising regions and distinguishing parameters of higher importance from those with less influence. Next, an exploitation phase follows to squeeze out the best possible results. Commonly this is done within reduced regions, searching for local optima, or within a subspace in which some of the less important free variables are frozen. Finally, selected variants are analysed and compared to the baseline, possibly at higher grid resolution and for conditions (and in disciplines) not considered during the optimisation.

Format

Optimisation problems are cast into a standard format so that available mathematical techniques can be put to use without need for individual adaptations. Five elements have to be written down:

- Objective(s): What shall be improved (i.e. minimised or maximised)?
- Free variables: What can be changed (and is under control of the team)?
- Constraints: What needs to be observed (making a design feasible or infeasible)?
- Fixed parameters: What influences the system but is kept (or assumed) constant?
- Noise: What influences the system but is beyond control?

In shape optimisation using CFD, objectives and constraints are non-linear functions of the free variables. Free variables are mostly real numbers with some integers that represent topological information (e.g. number of blades) and usually have lower and upper bounds which need to be chosen with care. Tight bounds give a small design space while loose bounds offer more room for improvements.

Constraints are subdivided into inequality and equality constraints. Inequality constraints describe limits up to which a design is still acceptable. For example the shortest distance between the shape to optimise and another object must be larger than a given value (a hard-point constraint). Inequality constraints are often considered via penalty functions (or barriers). The idea is that objectives are artificially worsened by adding an extra term (i.e. the penalty) as soon as a variant is found to be infeasible.

Equality constraints describe characteristics that need to be met exactly, for example the volume enclosed by a component has to equal a given value (Fig.3). An elegant solution of handling an equality constraint is to incorporate it directly into the parametric model. This not only guarantees feasibility with regard to this constraint but may even help to reduce the number of free variables.

Sometimes it is quite obvious what shall be regarded as an objective (e.g. resistance, pressure drop) and what needs to be handled as constraints (e.g. distance to a hard-point). However, there are design tasks for which several performance measures can serve either as objectives or as constraints. If in doubt a final decision can be made on the basis of an exploration.

Taking the time to write down objectives, free variables and constraints explicitly is more important than it may initially seem. It is a team-building exercise to reflect what is really important and what may be omitted after all.

Components

Typically, a parameter-based optimisation project involves the following components:

1. Variable geometry: A parametric model is developed and a shape variant is created as an instance of the chosen parameter values.
2. Pre-processing: The variant is pre-processed (e.g. generation of a watertight triangulation of the shape) to enable the simulation(s).
3. Simulation: For variants of interest one or several simulations are undertaken, by discretising the fluid domain (e.g. by generating a volume mesh) and solving the governing flow equations.
4. Post-processing: Variants and their flow data are post-processed (e.g. visualising flow fields for comparison).
5. Optimisation and Assessment: Variants are produced and assessed in accordance to the selected optimisation strategy, repeating the sequence from variable geometry to post-processing again and again.

These five components constitute a synthesis model, tightly coupling CAD and CFD. The actual sequence of creating a specific shape, discretising this shape and, subsequently, the fluid domain, doing the number crunching, collecting the data and, finally, assessing the current design for objectives and constraints is repeated many times. The chosen algorithms, as will be explained below, decide how variants are brought about and how many are considered. Today, if simulations take a couple of hours per case several hundred variants are studied. Frequently, this is done over the course of a long weekend or by distributing the heavy work load of simulation to an internal cluster or to a High Performance Computing (HPC) facility.

Exploration

When coping with multi-dimensional design spaces a team has to trade resources against insight. To do so with high efficacy, Design-of-Experiments (DoE) have been developed. These are mathematical algorithms that economically create as much understanding as possible [6].

In general, an exploration – also called a design study – helps to:

- Understand the design space and identify regions of interest
- Find favorable variants
- Evaluate sensitivities, possibly leading to a reduction of free variables
- Get an appreciation of trends and the potential for further optimisation
- Elucidate what should be treated as an objective and what as a constraint
- Provide the input data for building a meta-model if wanted

Exploration is an exhaustive search in which a prescribed number of variants are created by equidistantly changing one parameter at a time. If you have two free variables and want to afford just three

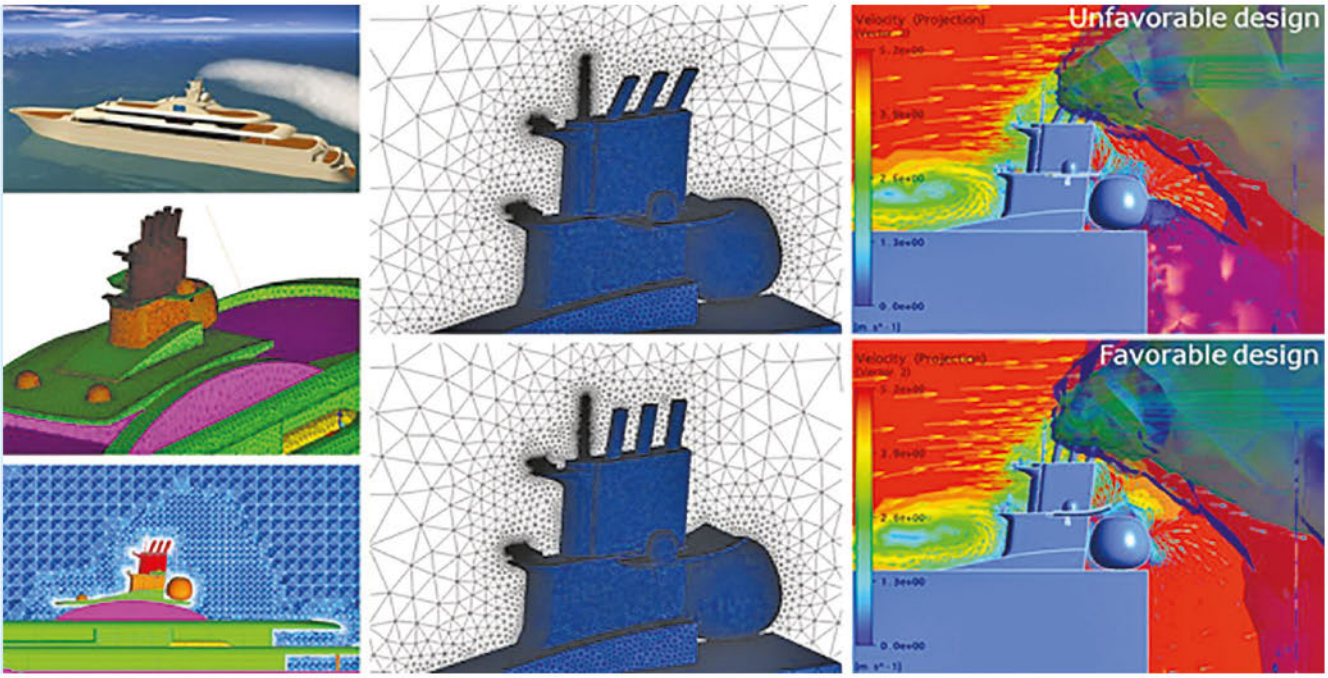

Fig.3: Funnel design study with unfavourable and favourable designs from DoE (Compiled from Harries and Vesting (4))

guesses in each direction you end up with a total of nine variants (i.e. a grid of three by three). For three variables you already need 27 variants (three by nine). It is easy to see that this scales up too quickly to be successful for expensive simulations. Consequently, other strategies were developed that deliberately leave out points in the design space that may not be absolutely necessary. Two popular algorithms are the Latin Hypercube (a factorial method) and the Sobol sequence.

Exploitation

As soon as regions of interest in the design space are known from the exploration phase an exploitation phase – also called formal optimisation – is started. Its purpose is to find further designs that outperform all designs known so far.

Usually, several optimisation runs are conducted. The team selects a handful of the more promising designs from the exploration phase.

Optimisation strategies are then put to use to systematically change the free variables in order to iteratively advance towards (at least local) optima.

Ideally, the exploitation would yield a true optimum. However, resources rarely permit that optimality conditions are strictly met. For mathematical proof first and second derivatives of the objective(s) with respect to all free variables would have to be computed, which is very expensive. As a consequence, a more humble approach is taken in most industry projects. The best variant is simply chosen from several improved designs. Pragmatically, even though nobody actually knows if some superior design was still out there, yet to be discovered, the final shape is at least better than its baseline.

Example

An example will now be presented to illustrate practical shape optimisation using CFD, steming from an industry project realised by coupling CAESES to the state-of-the art RANS solvers utilised by the different design teams on a daily basis (further examples along with animations can be found at www.caeses.com/industries/case-studies).

For a mega-yacht the exhaust funnel was studied with regard to gas contamination on the upper deck while at anchor in calm weather, representing the so-called "party condition". The fluid domain was discretized using ICEM while the simulations of the external thermo-fluid dynamic field were performed with ANSYS CFX (www.ansys.com).

Fig.3 shows an impression of the yacht along with its plume as emitted from the auxiliary engines, close-ups of the grid and two representative designs. The parametric model within CAESES allowed varying the length and angle of the exhaust pipes along with the size and shape of various deflectors. As an objective for minimisation the volume fraction of exhaust gas integrated over a plane downstream of the funnel was considered. An overnight Sobol of 50 variants was run by CAESES on a small cluster so as to identify unfavorable and favorable designs as needed for styling decisions. It can be seen in Fig.3 that longer and steeper funnel pipes in connection with extended and more strongly curved deflectors yield tangible reductions of exhaust gas.

Further issues

As pointed out at the beginning of the paper, for brevity many important issues are not elaborated here. Nevertheless, they should be mentioned in order to broaden the picture.

To start with, the world is multi-objective and so is design. Sometimes it is possible to express all objectives in the same unit (mostly in economic terms) or to normalise and mix objectives that are of different nature. Very frequently, however, objectives cannot be made directly comparable. To solve

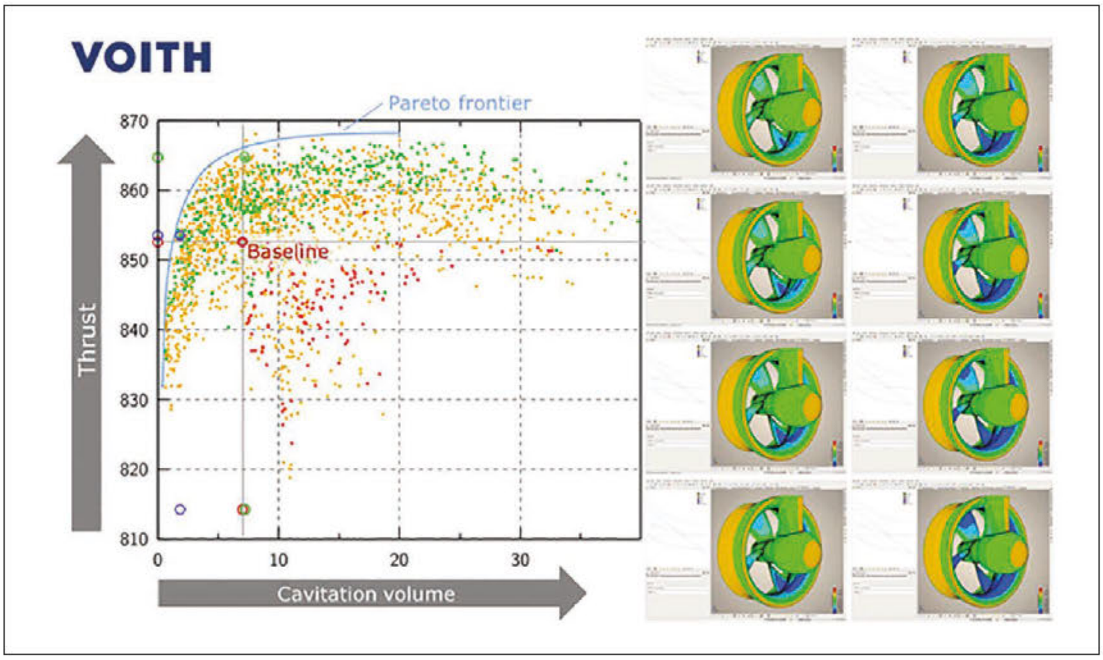

Fig.4: Comparison of performance for competing objectives for hundreds of variants along with representative instances of the propulsion system (Courtesy of Voith Turbo www.voith.com)

this predicament Pareto fronts can be studied (Fig.4). If a feasible design cannot be further improved for one objective without deteriorating any other objective, the solution belongs to the Pareto set.

Multi-objective optimisation often refers to looking at several objectives that belong to the same engineering discipline, say hydrodynamics. In naval architecture a typical multi-objective problem is to consider resistance, propulsion and sea-keeping at the same time. A multi-disciplinary optimisation is established as soon as several disciplines are involved, say hydrodynamics, structures and economics.

Sometimes, this is again cast into a single-objective problem in which several objectives are normalised (e.g. with baseline performance), weighted (e.g. according to frequency distribution) and summed up. For example, a ship typically sails at different speeds and drafts. A handful of loading conditions are combined so as to yield the objective for a robust optimal solution. Similarly, the blades of a turbine have to be really good at design point but also need to deliver a large operating range. Again, so as to avoid overbreeding a few representative conditions can be taken into account simultaneously.

Sensitivities also need to be considered in the context of noise and deterioration. The former is typically associated with fluctuating conditions such as spread in material property and deviations in production accuracy. The latter may simply stem from the wear and tear encountered after years of work. Therefore, it needs to be judged if the ranking of variants will actually remain true even if conditions slightly differ or change.

Summary

Parameter-based optimisation is applied during both initial and detailed design. Increasingly, shape optimisation using CFD is done early on when the insight and the potential for performance gains are highest. In order to be able to undertake optimisation projects special parametric models are required, focusing on engineering rather than production. They encompass partially-parametric (e.g. free-form deformation) and fully-parametric models. Dedicated upfront CAD software for variable geometry complements the traditional CAD software, offering parametric modelling as needed for shape optimisation. *NA*

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