THE NAVAL ARCHITECT

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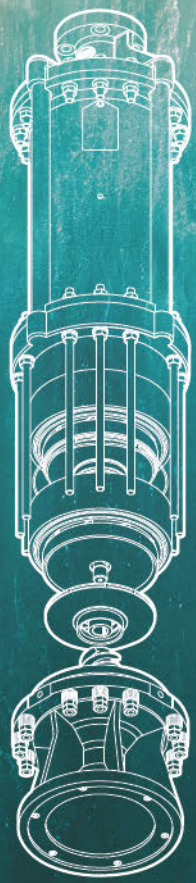
South Korea / Decarbonisation / Safety / CAD/CAM

October 2020

RIDE THE WAVE

Of the LNG marine expansion



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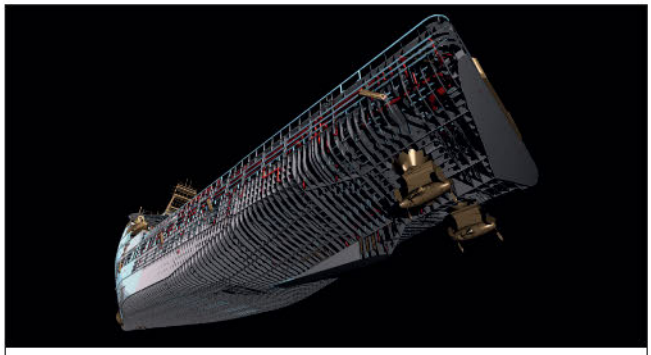

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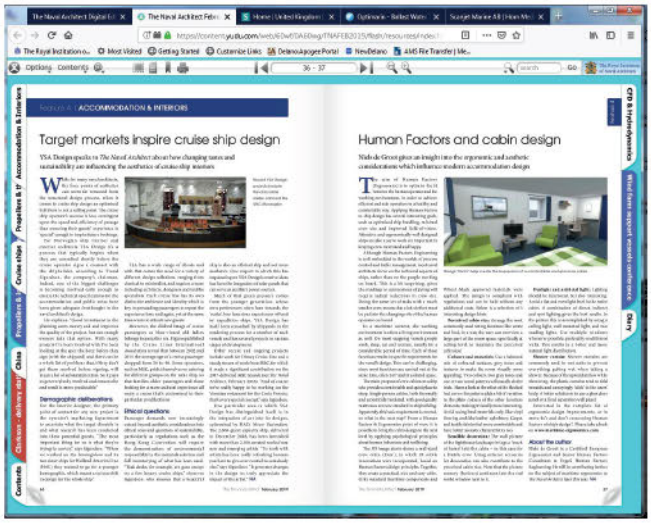

Target markets inspire cruise ship design

Human Factors and cabin design

RINA-QINETIQ

Maritime Innovation Award

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

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

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

Nominations are now invited for the 2020 Maritime Innovation Award. Individuals may not nominate themselves, although employees may nominate their company or organisation.

QINETIQ

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

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

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

Nominations should arrive at RINA Headquarters by 31st January 2021.

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

RINA - Lloyd's Register

Maritime Safety Award

The Institution believes that safety at sea begins with good design, followed by sound construction and efficient operation. Whilst naval architects and other engineers involved in the design, construction and operation of maritime vessels and structures do not have a patent on such issues, nonetheless their work can make a significant contribution.

The Institution also believes that it has a role to play in recognising achievement of engineers in improving safety at sea. Such recognition serves to raise awareness and promote further improvements.

The Maritime Safety Award is presented by the Institution, in association with Lloyd's Register, to an individual, company or organisation which has made a significant technological contribution to improving maritime safety. Such contribution can have been made either by a specific activity or over a period of time. Nominations may be made by any member of the global maritime community, and are judged by a panel of members of the Institution and Lloyd's Register. The Award will be announced at the Institution's Annual Dinner.

Nominations are invited for the 2020 Maritime Safety Award

Lloyd's Register

Nominations may be up to 750 words and should describe the technological contribution which the individual, company or organisation has made in the field of design, construction and operation of maritime vessels and structures.

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

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

Nominations should arrive at RINA Headquarters by **31 January 2021**

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hq@rina.org.uk

Sustaining human resources

Kitack Lim has been highlighting the humanitarian crisis faced by seafarers. Source IMO

2020 is continuing to be a year that many of us would like to forget. At the time of writing it's starting to look like a second wave of Covid-19 is now inevitable in the UK and that at the very least social distancing restrictions will be in place for a further six months, potentially even another lockdown. Tentative plans for a reopening of RINA's London offices in October also appear likely to be put on hold.

That situation is being mirrored in many other countries and the impact of the pandemic on maritime economics was unavoidably one of the dominant discussion topics at this year's conference for the International Union of Marine Insurers, which took place online on 14-25 September. In a presentation, Clarkson Research Services' managing director Stephen Gordon said that almost a billion tonnes of trade would be lost this year, amounting to around 4.6% to tonne miles, comparable with the 2008-2009 financial crisis but not as severe as it might have been.

It's been a very mixed picture for the different sectors. On the plus side for tankers, the 17 million barrel drop in oil demand in the second quarter leading on to some of the best ever rates as ships were deployed for offshore storage. Container ships peaked at 11% idle capacity but the lines managed circumstances well with blank sailings and slow steaming (to the extent that in some cases it's been more cost effective to travel around the Cape of Good Hope than pay to pass through the Suez Canal). Car carriers have suffered from a significant drop in demand, with projections that five million less vehicles will be transported this year from the usual 21 million. But these losses are dwarfed by those of ferries (44% down) and of course cruise (down by 88%).

After the initial panic of February and March most shipyards in China and South Korea have been able to resume work so there has only been a marginal drop in deliveries. The low orderbook of recent years (representing just 10% of gross tonnage at the start of 2020) compared to the more reckless times of 2008 (when the orderbook represented 52% of possible gt) means the effects should prove far less catastrophic than they might have been. Indeed, there is a prevailing sentiment that this lull should be seen as an opportunity for shipowners to take stock and make more informed decisions about green technologies. The concern perhaps is that may become an excuse for more prevarication.

But there are more urgent repercussions from Covid-19 and IMO Secretary General Kitack Lim used World Maritime Day (24 September) to highlight the plight of the 800,000 seafarers who remain either stranded at sea or unable to return to their vessels due to restrictions, with many governments still not recognising them as key workers.

The theme for this year's event, presumably decided upon long before the pandemic, was 'Sustainable Shipping', which might ordinarily have focused on issues such as efforts towards decarbonisation and other green concerns. However, the care for and management of human resources is likely to become a vital component of that and one that maritime can ill afford to ignore. The seafarer predicament is another example of how shipping only really enters the broader public consciousness when there's some kind of disaster, be it environmental or humanitarian.

Given such negativity, and the competition for their services from other industries prepared to pay as much if not more with none of the inconvenience, why should Generation Z (those born in the 2000's) find anything appealing about going to sea? As I heard one commentator suggest earlier, the very idea of a maritime career sounds like a relic of the industrial age.

Being a publication primarily orientated towards naval architects there could be an inclination simply to consign this to the 'human element' column, but there are repercussions too for ship design. Some may seem comparatively modest, such as efforts to make ship accommodation quarters more attractive and inhabitable living spaces (although I imagine this is of limited consolation to crew separated from family for 18 months). Others relate to the roles and responsibilities of tomorrow's seafarer. How many crew will be needed onboard future smart ships and how will they spend their time if more aspects of the operation are managed onshore?

Most answers to that still appear to be speculative and come with a whole other set of questions about training and education. But as with green technologies, this may be the time when it ought to start being addressed. In the drive towards optimisation, both in ship design and onshore infrastructure, the needs of the seafarer have been low on the list of priorities. If we want our best and brightest to work these vessels they will need to be convinced that they are valued. *NA*

Emissions control

MHI to trial CO_2 capture system

Mitsubishi Heavy Industries' (MHI) Mitsubishi Shipbuilding will test the world's first marine-based demonstration of an at sea CO_2 capture system onboard a "K" Line coal carrier.

Mitsubishi Shipbuilding is working on the two-year Carbon Capture on the Ocean (CC-Ocean) project in cooperation with Kawasaki Kisen Kaisha, Ltd ("K" Line) and Nippon Kaiji Kyokai (ClassNK). Together, the companies will confirm the equipment's use as a marine-based CO_2 capture system using trial operations and measurements on a small-scale ship-based demonstration plant, for which planned manufacturing is mid-2021.

To achieve this, the design of an existing CO_2 capture system for onshore power plants will be adapted for the marine environment, then installed onboard an in-service coal carrier for Tohoku Electric Power, operated by "K" Line.

The project aims to identify potential risks and run operability and safety evaluations, from which Mitsubishi Shipbuilding will determine the system's specification requirements as a marine-based device and methods for making the plant more compact. Thus, the findings will influence future technology development and CO_2 capture systems intended for use on exhaust gases of marine equipment and ships.

MHI states that the CO_2 captured will provide significant GHG reductions and can be repurposed as raw material in synthetic fuel or as a source for enhanced oil recovery (EOR) processes.

The CC Ocean project is also supported by the Maritime Bureau of Japan's Ministry of Land, Infrastructure, Transport and Tourism (MLIT), as part of its own assistance initiative for R&D of technological advancements in marine resource development.

Concept illustration of the CO_2 recovery demo plant

Classification societies

Lloyd's Register transitions to new CEO

Current Lloyd's Register (LR) CEO Alastair Marsh will retire from his role in the LR Group Board on 31 December 2020 and will be succeeded by LR's marine & offshore director, Nick Brown.

Marsh, who intends to transition into non-executive and advisory roles, reflects on his five-year tenure as CEO: "I have had the pleasure to work with so many committed and talented colleagues and I am enormously proud of everything we have achieved together, supporting our clients while fulfilling our purpose to make the world a safe place. […] I am very confident that LR will continue to prosper under his (Nick's) leadership, building upon our strengths and embracing new opportunities."

LR's future CEO, Nick Brown, who will continue in his current role as marine & offshore director until the new year, comments: "My new role comes at a time of change – the pandemic, global economic recovery and climate change – and I am confident that Lloyd's Register has both the agility and resilience to survive and thrive."

Brown will take over as LR's group CEO from 1 January

Fuels

BIMCO publishes VLSFO quality survey

BIMCO has published its industry survey on the transition to low-sulphur fuel oil, which has revealed quality and safety issues that will continue to challenge the maritime sector.

The survey released by BIMCO, Intercargo, Intertanko and the International Chamber of Shipping (ICS), was open between 24 February and 6 May. It focusses on properties of IMO 2020 compliant fuel oil that can potentially lead to problems onboard, with increased sludge deposits and wax appearance found to be the most common operational issues experienced.

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Other problematic low-sulphur fuel oil traits can include clogging of fuel pipes, preheaters, fuel separators and fuel filters, fuel pumps getting stuck, fuel injection problems and poor ignition of fuel oil.

The feedback also shows a worldwide challenge of fuel characteristics and limits being off specification, most often in total sediment, aluminium plus silicon, pour point, ash, flash point, acid number and viscosity.

Further, the survey indicates that sulphur content is one of the most frequent parameters recorded as off specification during post-bunkering fuel oil tests, which suggests non-compliance with MARPOL annex VI.

Classification societies

IRClass attains USCG recognition

The Indian Register of Shipping (IRClass) has received authorisation as a Recognised Organisation (RO) by the US flag administration.

The recognition acknowledges IRClass' efforts to meet the United States Coast Guard's (USCG) stringent safety and quality requirements with particular emphasis on environmental protection.

IRClass now has authority to undertake statutory survey and certification services on US-flagged ships on behalf of the administration, which the classification society states is a significant development reflecting its growing global profile.

The society has also gained recognition from the EU in 2016, as well as flag states such as Denmark, Netherlands, Cyprus and more. Collectively, the flags that have awarded IRClass authorisation equate to 58% of the global dwt tonnage.

IRClass executive chairman, Arun Shara, comments that: "IRClass is on a strong and continuous growth path and this important recognition from the US Coast Guard only reaffirms the technical expertise and growing capabilities of the organisation."

Cruise ships

Carnival delays its cruise deliveries

Cruise ship giant Carnival Cruise reports delays in the expected delivery of its new vessels, with a reduced outlook for newbuilds on order beyond 2020.

Carnival had been originally anticipating the delivery of four cruise ships this year but now expects to take on two new vessels between now and the end of November. *P&O Iona* is awaiting acceptance from Meyer Werft following its completion in Germany. Elsewhere, Princess Cruises' *Emerald Princess* and Costa's *Costa Firenze* are both nearing completion by Fincantieri.

P&O Iona has completed construction and is still due to be delivered this year

Originally scheduled for nine ship deliveries in the next two years, Carnival now awaits delivery on just three additional vessels during the fiscal year 2021. Further, the company has orders for 16 cruise ships due for delivery up until 2025.

Efforts to slow deliveries of new vessels and improve the efficiency of its fleet arose after Carnival announced a loss of almost US$3 billion in Q3 2020, US$1billion of which was in impairment charges.

Alternative fuels

ABS introduces alternative fuel ready guide

The American Bureau of Shipping (ABS) has launched its 'Alternative Fuel Ready' approach, a guide to support the industry's adoption of new fuel technologies.

Published as part of the society's 'Guide for Gas and Other Low-Flashpoint Fuel Ready Vessels', the Alternative Fuel Ready model will help shipowners either build new vessels or convert existing ships to use LNG, methanol, ethane, LPG, hydrogen, ammonia, or any other low-flashpoint fuel.

The approach, which replaces ABS' previous 'Guide for LNG Fuel Ready Vessels', also encompasses support for shipowners intending to order conventionally powered vessels designed to be adapted for low-flashpoint fuels in the future, aka 'Alternative Fuel Ready'.

According to Gareth Burton, ABS vice president for technology, the guide's concept allows shipowners to plan their future fleets to adapt to the evolving regulatory and technological landscape. It identifies key technical issues relevant to developing vessels capable of low-flashpoint fuel operations and includes a series of corresponding notations as well as a three-level programme of alternative fuel readiness through concept, design and installation.

ABS adds that its guide was produced in anticipation of an emerging trend for low-flashpoint fuels, which it expects to increase as maritime looks to IMO 2030 and 2050 decarbonisation targets. *NA*

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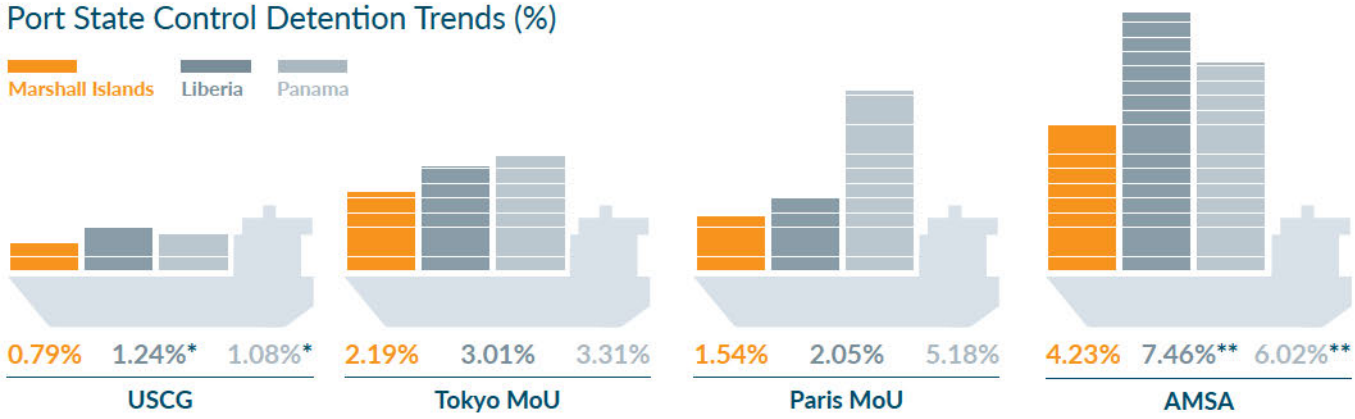
Port State Control Detention Trends (%)



* *Liberia and Panama are targeted for additional PSC examinations by the USCG for having a detention ratio up to two times the overall detention average.*

Sources: 2019 Port State Control Annual Reports.

** *Liberia and Panama have exceeded the overall AMSA average detention rate over the three years from 2017–2019 and Liberia is listed among the top five worst detention rates by flag State.*

International Registries, Inc.
in affiliation with the Marshall Islands Maritime & Corporate Administrators

info@register-iri.com

LNG taking off as SMM exhibition goes AWOL

The absence of maritime's biggest showcase hasn't meant an absence of announcements, writes Malcolm Latarche

Ordinarily, September in an even numbered year would see news pages dominated by reports of new equipment exhibited or announced at SMM in Hamburg and by views and opinions expressed at the many conferences, seminars and workshops that are held alongside the exhibition.

Unfortunately, the Covid-19 pandemic has put paid to that and reading between the lines of an announcement issued by the SMM organisers on the day the exhibition was due to open, it would appear that the postponed event now scheduled to be held in February next year may not be in the familiar format that most would expect.

SMM 2021 will, it seems, be a hybrid event, combining the exhibition halls with an online programme to cater for visitors who would rather participate from a distance. Just now the organisers are looking at being able to make sure that social distancing rules and reliable contact tracing can be implemented. Visitor numbers will apparently be limited although exactly how has not yet been explained.

There was, however, the spirit of SMM noticeable in much of September news because one of the main themes of the conference programme would have been the decarbonisation of shipping, a subject that is quite evident in news from a variety of sources.

So far most interest in 2020 has been the potential of ammonia but two announcements serve to remind the industry that fuel cells, on the back burner for several years, are still seen as having a role to play.

Canada-based Ballard Power Systems employed an online launch for what it says is the first module designed for primary power propulsion. Ballard's FCwave fuel cell is a 200kW modular unit that can be scaled in series up to almost any level. Rob Campbell, Ballard's chief commercial officer says: "Ballard is focused on Heavy- and Medium-Duty Motive applications, particularly where requirements include heavy payload, extended range and rapid refuelling". He adds that this land use experience can be transferred to marine. To that end, the company is planning to start production in Denmark and is currently engaged in obtaining type approval process from DNV GL.

Aside from the Ballard announcement and another from Japan where a consortium is exploring fuel cells, almost all other developments suited to long distance shipping concern using alternative fuels in internal combustion engines. Ammonia, methanol and LPG are on the list for the mid term but the present favourite to replace oil in the short term is easily LNG. Its position was reinforced throughout September with several ships intended to run being launched, named or delivered.

The month opened with a naming ceremony at Shin Kurushima Toyohashi Shipbuilding in Japan for NYK Line's new LNG-fuelled *PCTC Sakura Leader*. Scheduled for delivery in October, the vessel is the first large gas-fuelled car carrier to be built in Japan.

On 16 September, Eastern Pacific Shipping took delivery of the 14,800TEU *CMA CGM Tenere*, the first VLCS built to run on LNG immediately rather than being merely LNG ready (see also p.19). As the name suggests, the vessel is being operated on charter by French liner major CMA CGM. Delivery of the vessel was a fitting prelude to the delivery on 22 September of the world's largest LNG-fuelled container ship and CMA CGM's new flagship the 23,000TEU *CMA CGM Jacques Saade*.

Both CMA CGM vessels will be bunkered by *Gas Agility*, the world's largest LNG bunker vessel. The ship itself was delivered in April this year but the naming ceremony took place in Rotterdam only on 18 September.

Another significant LNG fuelled vessel launched in September was *Eleanor Roosevelt*. Being built for Balearia in Gijon, Spain the vessel will be the fastest ro-pax ferry powered by reciprocating engines when delivered early next year. Its Wärtsilä 31DF engines will give it a service speed of 35knots.

However, in terms of significance, it was the launch by BeHydro of its hydrogen-burning diesel engine that must be at the top. The joint venture between Belgian organisations, shipowner CMB and engine maker Anglo-Belgian Corporation (ABC) unveiled its prototype engine on 18 September.

The engine is based on ABC's DZD series of dual-fuel engines and runs on a mixture of hydrogen and diesel or MGO. Diesel is necessary as a pilot fuel and when necessary the engine can run on diesel or biodiesel.

BeHydro has already received its first order for a pair of 1MW dual-fuel engines that will be installed onboard the *HydroTug* which was commissioned by Port of Antwerp and is planned to be operational some time next year. With the launch of the new engines, BeHydro explains that in a first phase of production, up to 100 hydrogen-powered engines can be produced per year. In addition, BeHydro is developing a mono-fuel spark ignited hydrogen engine that is also supposed to be ready for production next year. *NA*

Data analytics

Kongsberg signs JAWS software agreement

Technology specialist Kongsberg Maritime has signed an agreement to deliver the patented draft and trim optimisation software, Just Add Water System (JAWS), which has been developed by Shell.

Kongsberg Maritime's K-IMS digital suite will be the primary outlet for distributing the JAWS software. As an application on the K-IMS platform, JAWS will be accessible to hundreds of existing LNG customers utilising the digital suite, as well as new customers. K-IMS combines data-logging and communications together on one platform for a comprehensive information flow for fleet owners, charterers and third parties.

Egil Haugsdal, president of Kongsberg Maritime, says that the agreements between the two companies sets an encouraging example to the industry, showing that shipping can become greener through close collaboration.

Shell developed its JAWS software with the University of Southampton (see *TNA* Sept, pg 36). The technology uses historic, high-frequency data from the vessel to identify optimal conditions experienced on previous voyages. This allows the JAWS software to recommend draft and trim enhancements, for vessel's operating at any speed, to minimise fuel consumption and emissions.

Classification society DNV GL has also been involved in the development of JAWS, through its Technology Qualification (TQ) process; it has assessed the methodologies employed by JAWS and ensured that the software's calculations are based upon accurate and reliable use of data.

JAWS has been utilised by over 50 vessels to date and this year Shell plans to increase its distribution across a further 20 vessels in its LNG fleet.

Data analytics

SMWS plans fleetwide ABB diagnostics installation

Shanghai Ming Wah Shipping (SMWS) will equip its entire 12 bulk carrier fleet with ABB's engine analytics software, ABB Ability Tekomar XPERT, after a successful trial on two of its vessels that began in February 2019.

Later, in June 2019, SMWS installed Tekomar EXPERT on four of its vessels and has since seen a fuel saving of 0.62tonnes per day on each ship. The software's saving potential is particularly significant on high-powered engines and it is reported that one vessel, running on a MAN B&W 6S42MC engine, experienced a 4.3g/kWh fuel saving.

In July this year, the company extended its order by a further eight vessels. Collectively, this could dramatically improve the vessels' environmental performance and, when employed across all 12 vessels, may reduce CO_2 emissions by a predicted 5,800tonnes annually.

Tekomar XPERT provides pre-emptive warnings and recommendations to prevent engine failure by analysing the vessel's turbocharger and engine performance. ABB highlights that, in one instance, the technology detected high cylinder pressure in an engine on one of SWMS' bulk carriers, an issue that increases the cylinder component's mechanical load and can lead to operational hazards.

The system works on any engine, irrespective of age or type, and is built on ABB's Ability platform, which brings the company's digital solutions together onto one interoperable platform.

ABB Turbocharging and Shanghai Ming Wah Shipping sign the order to install ABB Ability Tekomar XPERT across the shipowner's fleet

Weather routing

JWA promotes weather routing service

The Japan Weather Association (JWA) unveiled a weather forecast and optimum ship routing service, POLARIS Navigation, which the company says enhance both financial and ecological benefits for vessel operations.

The product, launched in March 2020, uses high-precision weather and ocean weather forecasting information technology, as well as ship propulsion performance estimation equipment which is calibrated for individual vessels.

According to JWA, its POLARIS Navigation technology is suitable for both international and domestic voyages and during trial operation aboard a large coastal ro-ro carrier, the company says that with this technology, a 4.2% reduction in energy consumption has been achieved.

JWA's system allows for efficient operations when working in combination with marine equipment from Japan Radio Co. Ltd (JRC).

Mirai Shipbuilding installed JRC's high-speed satellite communications system, which utilises Inmarsat's Fleet Xpress (FX), onboard the fishing vessel *Shofuku Maru No.1*. In this case, POLARIS Navigation fitted for voyage schedule assistance and forecasting data, without considering the data volume required. POLARIS Navigation can also be linked with JRC's JMR-5400 radar, allowing *Shofuku Maru No.1*'s calculated optimal route to be exported to its autopilot.

Polaris Navigation is part of JWA's wider suite of POLARIS services, which also includes; POLARIS Forecast – for weather and ocean forecast data onboard, POLARIS Hindcast – providing weather and ocean data relating to the ship's track through a web application programming interface (API) and POLARIS Plus – an online service for monitoring vessels which installed POLARIS Forecast and POLARIS Navigation.

Propulsion

FuelOpt exceeds ro-pax saving predictions

Lean Marine's propulsion automation system, FuelOpt, has surpassed its projected fuel savings on vessels for ro-pax operators Color Line and Bohai Ferry.

This year, two of the world's largest ro-pax vessels, Color Line's *Color Fantasy* and *Color Magic*, were equipped with FuelOpt, a system that automatically optimises propulsive power based on set power, speed and consumption commands in order to improve fuel savings. After continuing its full operations this summer, *Color Magic* experienced its lowest weekly consumption to date.

In 2019, the FuelOpt system was installed onboard Chinese ro-pax operator Bohai Ferry's *Bohai Bouzhu* with the company aiming to improve the operational efficiency of its fleet. Since then, the operator has reported achieving an average fuel savings of 12% or above.

Mikael Laurin, Lean Marine CEO, highlights that the company is happy with the reported fuel savings, which confirms the reductions that FuelOpt is capable of: "Every vessel operating with FuelOpt represents a step towards a greener future. With FuelOpt in operation, up to 15% direct fuel savings and emission reductions are possible depending on the type of propulsion, trade and existing system settings for the vessel."

Lean Marine claims that, in recent years, the demand for its FuelOpt system in the ro-pax sector has increased with businesses including Stena Line, Color Line, Bohai Ferry and Viking Line making up a total of 25 orders for ro-pax vessels by September this year. The company states that the uptake in investment is due to FuelOpt delivering tangible fuel savings and CO_2 emission reductions.

Ballast Water Management Systems

USCG and G8 type-approvals for BWTS'

Glosten spinoff and ballast water treatment system (BWTS) oneTank has attained type-approval from the United States Coast Guard (USCG), applicable for models with maximum treatment volumes up to 4,000m³, with USCG confirming that oneTank's system meets 46 CFR 162.060 BWMS requirements.

The oneTank system can treat up to 4,000m³ within 30 hours. Its treatment process includes an in-tank chemical injection, where a bulk chemical dosage is circulated throughout the vessel's ballast tank, and an in-tank neutralisation prior to discharge. Ballast water is treated within the ballast tank, which allows for flexible uptake, treatment and discharge of ballast water in order to meet the ship operators schedule.

Meanwhile, Techcross has received the new G8 IMO BWMS code from the Korean government for its ballast water management system (BWMS), ECS. The ECS has a freshwater holding time of 23 hours, an operational temperature of more than or equal to -2°C, feed salinity of 1PSU or above, from 1.5PSU including the mixing solution required for fresh water.

The company previously attained the same approval for its newly developed BWMS, ECS-HYCHLOR, in February 2019, from the Norwegian government in conjunction with DNV GL/Norwegian Shipping Register. With its recent approval from the Korean government, all Techcross BWMS that employ direct and indirect electrolysis technologies have been given IMO BWMS CODE approval. *NA*

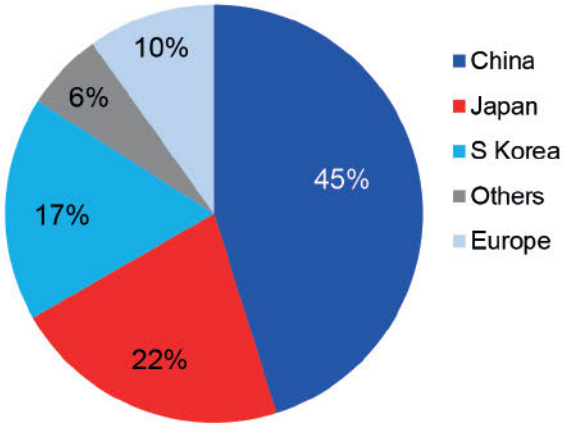
BWTS oneTank has received type-approval from USCG

Clarksons Research: Historical and Scheduled Deliveries Report

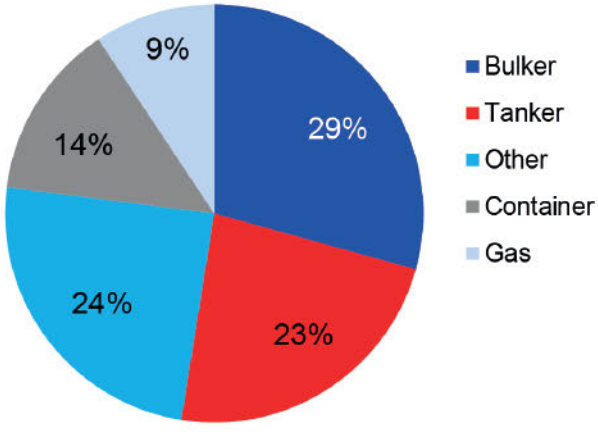
Data extract from World Fleet Register available at www.clarksons.net/wfr

Vessel Type	2009		2010		2011		2012		2013		2014		2015	
	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half
VLCC >= 200,000	33	20	30	24	35	27	27	22	21	9	14	10	9	11
Suezmax 125-200,000	22	22	26	11	26	18	30	15	23	4	4	4	7	3
Aframax 85-125,000	63	33	39	31	28	31	30	15	14	6	4	13	22	10
Panamax Tankers 55-85,000	26	12	15	16	19	10	9	6	7	5	3	1	2	1
Products 25-55,000	92	67	65	46	45	28	27	30	49	29	49	49	60	57
Products 10-25,000	6	5	7	7	8	6	13	6	9	4	1	8	4	0
Chem & Spec. 10-55,000	106	69	77	59	53	40	38	8	8	13	12	11	36	29
Tankers < 10,000	71	70	65	53	53	51	70	35	35	28	25	22	13	14
Capesize > 100,000	33	77	101	111	129	122	149	65	63	40	56	38	46	42
Panamax 80-100,000	27	21	60	61	81	97	140	94	101	68	62	35	57	41
Panamax 65-80,000	18	15	18	33	36	44	53	39	34	42	42	20	19	4
Handymax 40-65,000	84	100	168	166	199	198	228	146	147	119	98	102	144	121
Handysize 10-40,000	177	195	186	186	186	179	226	117	116	83	97	67	100	83
Combos > 10,000	0	0	3	2	3	0	0	0	0	0	0	0	0	0
LNG Carriers	22	17	15	12	5	10	1	2	4	13	14	19	16	16
LPG Carriers	25	18	18	18	16	14	13	8	22	16	14	14	25	40
Containers > 8,000 teu	21	14	29	33	48	30	51	28	51	33	59	42	58	62
Containers 3-8,000 teu	59	59	76	41	31	21	39	19	46	29	26	25	18	6
Containers < 3,000 teu	69	55	57	26	33	34	37	40	29	19	22	28	27	35
Offshore	11	19	21	25	27	22	30	10	11	19	32	30	25	13
Cruise Vessels	3	6	9	4	4	2	6	1	6	0	3	2	5	1
Passenger Ferries	11	7	10	13	11	10	11	8	6	6	12	8	13	8
Other	151	161	174	180	183	183	191	99	99	83	72	62	69	48
TOTAL	**1,130**	**1,062**	**1,269**	**1,158**	**1,259**	**1,177**	**1,419**	**813**	**901**	**668**	**721**	**610**	**775**	**645**

Orderbook by builder region (number of vessels)



Orderbook by sector (number of vessels)



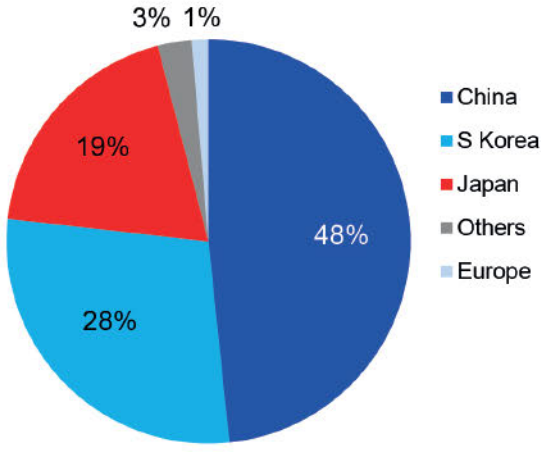
2016		2017		2018		2019		2020	Scheduled Orderbook		
1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Half	2020	2021	2022
23	24	29	21	21	18	39	29	21	22	28	11
8	19	35	22	25	7	23	3	11	22	26	18
31	22	36	28	26	24	41	12	11	14	52	25
7	11	10	11	7	6	6	7	3	13	6	3
60	42	39	25	27	22	50	46	45	43	71	19
3	2	6	6	8	6	4	4	4	6	4	0
43	38	38	31	45	41	34	28	27	38	27	8
23	16	24	28	42	37	20	25	22	44	27	3
64	39	55	20	30	21	31	49	62	58	70	24
71	40	75	27	39	25	69	64	90	73	96	15
1	2	6	1	2	2	1	2	3	4	0	0
124	94	125	54	58	33	56	77	85	67	99	38
85	46	69	31	47	42	48	39	31	53	63	11
0	0	0	0	0	0	1	2	0	2	3	0
15	18	20	12	32	23	22	20	15	31	65	35
49	33	45	17	26	9	16	13	22	24	39	18
37	26	34	36	47	23	27	23	12	29	56	16
2	0	2	5	7	3	6	1	1	4	7	0
39	27	35	42	50	38	43	54	40	98	85	12
25	19	18	24	25	13	9	9	4	40	28	11
8	2	7	3	8	4	12	10	6	14	31	27
6	15	20	10	11	18	15	16	7	34	41	15
50	60	50	54	49	46	55	51	33	106	120	37
774	595	778	508	632	461	628	584	555	839	1,044	346

Data includes all vessels with LOA estimated at >100m

The orderbook by year of delivery on this page is based on reported orders and scheduled delivery dates and do not necessarily represent the expected pattern of future deliveries

All data taken as of 1st July 2020

Orderbook (DWT) by builder region



Source:
Clarksons Research

A long way still to go

Leading women in the maritime industry virtually sat down and discussed what mechanisms for change can be put into place to improve diversity and gender equality in the sector

Last year, IMO's World Maritime Day was dedicated to 'Empowering women in the maritime community', and while this theme is a reflection of the many steps forward women's representation has seen in the past few decades, as of 2019 only 2% of women make up an estimated 1.2 million seafarers.

Maintaining gender diversity as a topic of conversation is a significant part of the challenge and vital for change. Despina Theodosiou, President of the Women's International Shipping and Trading Association (WISTA) International and Co-CEO at Tototheo Maritime, commented that: "In light of the huge restrictions we are faced with this year, we are pushing to see continued effort to ensure that diversity and gender awareness remain a discussion point wherever and whenever it needs to be."

Continuing the equality conversation is reflected in WISTA's work, and Theodosiou highlighted that for the larger part of 2019 it was focused on supporting IMO's theme of empowering women, ultimately signing an MOU with IMO in January 2020 to jointly ensure that progress made to promote diversity in 2019 is sustained into 2020 and subsequent years.

Alongside the association's other work, including establishing a women's speakers bureau, this Autumn WISTA plans to publish its IMO-WISTA study on the number of women employed in the maritime sector. The association also recently co-launched an online survey among women seafarers, in conjunction with Anglo-Eastern, ISWAN and ICS. The data collected will be used to update the onboard 2018 Anglo Eastern Gender Diversity Booklet, which addresses critical social, cultural and interpersonal issues that can obstruct the productivity of a shipboard team. Both are examples of published representative data, an area that is still significantly lacking that would improve transparency and create accountability within the industry.

WISTA International reaffirmed that 'Diversity, including gender diversity, is a responsibility for all and key to the sustainability of the maritime sector' upon signing its MOU with IMO

"We're missing a meaningful way of trying to find and collect data," said Dora Mace-Kokota, partner at law firm Stephenson Harwood, specialising in ship and offshore finance: "and until we have some kind of accountability in terms of publishing data, going back to it, analysing and understanding what it means, I don't think we can get anywhere meaningfully."

Aside from statistics that give a clear picture of women currently employed in the maritime industry, issues of diversity remain in both recruitment and retention. Women are seen less frequently in more senior roles and it was suggested that companies should seek to improve mentoring approaches and recruitment-level diversity training on unconscious bias.

From the perspective of the legal community, Mace-Kokota commented that there is a shift happening in the mentoring approach that could be adopted for maritime; companies are attempting to connect employees with those who have progressed higher than them in the work hierarchy, but who they still feel they are within touching distance of and can become. In other words, showcasing role models at every level of employment to create obtainable aspirations.

Mace-Kokota pointed out that many law firms are entering into so called 'active mentoring' and discovering that the relationship works both ways: "There are more senior staff and partners included in being mentored by more junior staff, in order to understand what the real challenges are and how they can help them […] It's a good way of bringing people up, but also educating people around us who might be a bit more resistant to change and to discuss change as well." Further to this, Theodosiou added that: "If we want to produce diversity then this needs to be included in mentoring too. It should not be that men mentor men and women mentor women, that way we're only helping an unwanted situation perpetuate."

To generate interest and diversify the entry-level workforce, Caroline Yang, CEO of Hong Lam Marine and President of the Singapore Shipping Association, called for active promotion of the maritime industry at education level, starting from an early stage with visits to schools. "We need to create that awareness and it has to be a sustained awareness, especially in the minds of young people, that maritime, akin to aviation, is an attractive sector to be in, and there is career progression and different areas in maritime. In short, we need to increase the visibility of maritime and no better time than now, with all the social media tools at our disposal," she concluded. *NA*

South Korea's gas powered resurgence

The 'Big Three' yards dominated orders for a second consecutive month

Figures published by Clarkson Research Services at the start of September indicated that South Korean yards secured orders for 23 vessels, with a compensated gross tonnage (CGT) of 630,000, representing 73% of global orders. By contrast China had 24% of orders, with 12 vessels.

However, global demand has been hit heavily by Covid-19, with orders between January and August this year only reaching 54% of 2019 levels. Moreover, it has been bolstered by bookings for LNG carriers, a ship type for which South Korea continues to leverage its significantly greater expertise over the Chinese yards.

This superiority was evinced in June when Korea's 'Big Three' shipyards – Hyundai Heavy Industries (HHI), Samsung Heavy Industries (SHI) and Daewoo Shipbuilding & Marine Engineering Co (DSME) – secured a US$19.2 billion deal to build 100 LNG carriers for Qatar Gas through to 2027, while CSSC-owned Hudong-Zhonghua Shipbuilding were awarded contracts for a more modest 16 units.

Among the other orders, Korea Lines has booked two LNG carriers from HHI, due for delivery in 2023 and under long-term charter to Shell. They comprise an option Shell has exercised on a previous contract for two vessels to be delivered in 2022 by sister company Hyundai Samho Heavy Industries (HSHI) and will join the fleet of Korea Lines' recently-formed subsidiary Korea LNG Shipping. Additionally, HHI and HSHI signed deals for two carriers each from unnamed Bermudan and European owners respectively.

Russian orders

Elsewhere, there are conflicting reports concerning 10 Arc7 ice class LNG carriers placed by Russian gas producer Novatek and Sovcomflot for the country's Arctic LNG 2 project. Having previously built 15 such vessels for the Yamal LNG project between 2016 and 2019, DSME appeared to be ideally placed to win further orders.

LR awards Digital Twin Ready AiP to HHI for gas containment tank

However, Russia is keen to develop its own shipbuilding capabilities and previously placed bookings for five such vessels from the Zvezda yard in late 2019 and early 2020.

To help Zvezda achieve the necessary expertise, last year it signed a technical cooperation deal with SHI to assist with construction. But there are concerns about both Zvezda's abilities to achieve the necessary standards and the capacity for additional orders, leading Russia to soften its stance on homegrown shipbuilding. It now seems likely that SHI, DSME, or a combination of the two will win the order for the 10 vessels, with a decision on the US$3 billion deal expected by the end of September.

HHI granted AiP

South Korea's pre-eminence with membrane gas containment technologies, as opposed to the Moss (Type B) favoured by Japanese shipyards, has put them in good stead over the last five years given its superior storage capacity (up to 40% greater). But they also have the upper hand with regard to the stringent requirements of LNG fuel supply systems, with all the Big Three having their own proprietary technologies.

In September, HHI took that evolution a step further when it was awarded an AiP by Lloyd's Register for its Digital Health Management (DHM) system for a Type B fuel tank following a joint development project between the two parties. The system, dubbed Hyundai Prismatic Independent IMO Type B Tank eXcellence (HiPIX), is a suite of software that uses sensor-based digital twin technology to generate real-time insight into the structural safety of the tanks.

The insights into the condition of tank components will allow owners to obtain survey credit and should lower through-life costs. It will be deployed for the first time onboard the world's first dual-fuelled ultra-large container ships, which are currently under construction at Hyundai Samho Yard for Eastern Pacific Shipping.

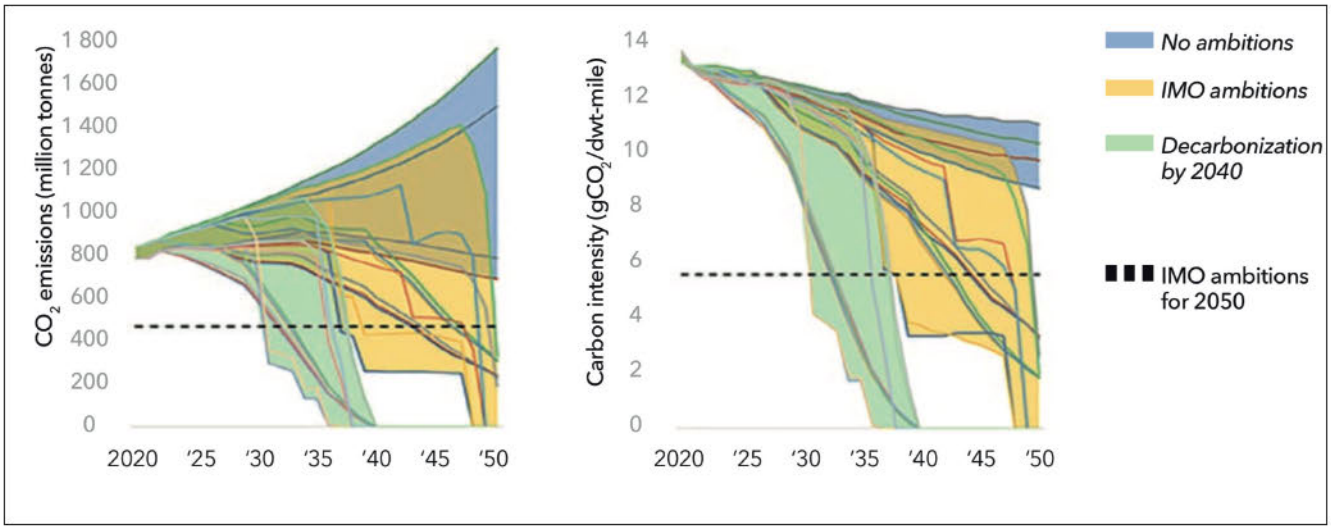
Merger delays

Meanwhile, DSME remains in the midst of the long running saga concerning its proposed megamerger with HHI. The latest hurdle was cleared in August when it received clearance from the Competition and Consumer Commission of Singapore, but in July the European Commission's probe has suffered a number of setbacks in its data collection due to Covid-19, and it's unclear whether a decision will be reached this year.

Given Europe's limited capacity for shipbuilding, experts think it's likely that approval will be granted with caveats restricting the merged entity's further expansion. However, the deal will still require the approval of China, which has hitherto remained silent on the matter, and Japan, which filed a complaint to the World Trade Organisation in February. *NA*

All tomorrow's pathways: maritime's energy transition

DNV GL's latest forecast on shipping's route to 2050 goes further than ever before in exploring the different scenarios



CO_2 emission (left) and carbon intensity (right) trajectories for the 30 scenarios modelled for the decarbonisation pathways. Source DNV GL

Perfect is the enemy of good, believes DNV GL CEO of maritime, Knut Ørbeck-Nilssen. "We are facing a situation where idealism and localism spell trouble… Shipping requires international regulations, however we do see that local and regional lawmakers are increasingly demonstrating impatience and distrust with the IMO's lack of progress."

Ørbeck-Nilssen's fear is that the road to decarbonisation will be compromised by a patchwork of localised regulation, as it has with other issues such as biofouling and ballast water discharge. Earlier in September, the European Parliament voted to include greenhouse gas (GHG) emissions from ships over 5,000gt in the emissions trading system, subject to approval by EU member states. It's a move which threatens to undermine the International Chamber of Shipping's initiative to create a US$5 billion R&D fund based on a mandatory contribution of US$2 per metric tonne of marine fuel that would be applicable across the world.

In order to achieve IMO's target of an overall 50% reduction in total GHG emissions by 2050 it's commonly accepted that the hard work must be done over the next decade. That entails a massive scale-up of new technologies and better fuel alternatives than is currently being realised. DNV GL anticipates that the regulations and incentives being drawn up to achieve this will begin to impact by 2023, with all the implications to costs, asset values and earning capacity which that entails.

Maritime Forecast to 2050

Published annually since 2017, the 'Maritime Forecast to 2050: Energy Transition Outlook' is intended as a tool to help shipowners navigate the technological, regulatory and market uncertainty of decarbonisation. It encompasses a library of 30 different scenarios for the evolution of the global fleet between now and the middle of this century, with different permutations of fuel types and technology systems. These are derived from three primary energy sources: electrofuels (fuels derived from renewable electricity), sustainably-sourced biofuels, and traditional fossil fuels utilising carbon capture and storage.

"Having 30 scenarios has allowed us to understand which of these drivers are more important and also the sensitivity of each and how much they impact on the choice of technology and fuel," explains Tore Longva, maritime principal consultant at DNV GL and the publication's lead author.

Each scenario belongs to one of three decarbonisation pathways: a reference one in which no further regulations are imposed on shipping, another in which shipping achieves the 50% targets set out by IMO in 2018's Initial GHG strategy, and an ambitious pathway where shipping becomes fully decarbonised by 2040.

Longva says: "We do see a lot of pressure with the European Parliament and society in general pressing for decarbonisation. IMO is going to review its strategy in 2023 and then every three years after that. The EU is probably going to press for harder regulations. [The 2040 pathway] is partly there as a reference as the most radical but it could be 2050 or anything in between."

Continuing the theme, there are also three key drivers, or uncertainties: the extremity of regulatory policy measures (e.g.

carbon pricing), the cost of fuel and energy, and how seaborne trade demand may change over the next 30 years. This year's study explores in greater depth the theme of fuel flexibility and foresees significant future roles for ammonia and methanol, alongside bio- and synthetic LNG.

At present, less than 0.5% of the current global fleet is using alternative fuels (including LNG) but that figure rises steeply to almost 10% when ships on order are factored in, according to data on DNV GL's Alternative Fuels Insight platform. These figures are based on the total number of vessels, taking into account smaller craft, but Longva points out that these are increasingly serving as a test bed for new technologies that can eventually be upscaled.

Notably, the report chooses to adopt a tank-to-wake approach in its forecasting. Longva explains: "We assume that the fuel has to be carbon neutral also from a well-to-tank perspective. All cost projections are made on basis of being carbon neutral in production; either fuels by green electricity, fossil fuels by onshore carbon capture or biomass. But we haven't projected the landside production of these fuels but we've assumed that at some point they have to be carbon neutral and provided for shipping's use."

LNG and ammonia

Ørbeck-Nilssen describes decarbonising shipping as a journey and it's long been the opinion of DNV GL that LNG is the first port of call. This year's report further underscores that message, albeit some of the more radical scenarios do bypass it entirely and see a direct switch from fuel oil to methanol or ammonia. Under IMO's current proposals it's anticipated that LNG uptake will continue for the next 20 years before ammonia takes over.

In order to explore the pros and cons of each permutation the report takes the generic example of a 2020-built Panamax bulk carrier. It was found that a vessel with "a robust engine and fuel system" – which is to say a dual-fuel LNG engine – was the best equipped to cope with most likely scenarios, though in the event of decarbonisation by 2040 it would require retrofitting to a carbon-neutral fuel during the 2030s. But even in this situation the space required for the original LNG engine and fuel system means that adequate space will have been set aside in the vessel design for fuel storage tanks.

'Planning for fuel flexibility could ease the transition and minimise the risk of investing in stranded assets. A structured, scenario-based approach to future-proofing will help in managing the decarbonisation risks,' the report notes.

Nonetheless, Ørbeck-Nilssen concedes that so far conversion to gas hasn't followed the projections of the original 2017 forecast. "I think what has been most difficult is the infrastructure and how much that impacts the whole decision. The technologies and regulations have been in place but when you order a ship you have to be certain that it's actually available and that takes a long time."

Longva adds: "There has been some very positive developments on the bunkering side. It was one of the major obstacles in the past but this is quickly diminishing, especially at the major hub." The report also concludes that synthetic LNG, derived from electrolysis, will have an important part to play as a transitional fuel for those vessels which cannot convert to ammonia.

Ammonia itself has seen some rapid progress during the past year, with engine manufacturers Wärtsilä, WinGD and MAN Energy Solutions (MES) also reporting progress with the development of ammonia burning engines. At the time of writing, rival classification society Lloyd's Register has just granted an AiP for an ammonia-fuelled tanker design jointly developed by Samsung Heavy Industries, MISC Berhad and MES.

Ørbeck-Nilssen says he is unsurprised by how quickly the ammonia technology is developing. "It fits very well into what I call the maritime renaissance. Because of the speed of other developments we're seeing quite an accelerated pace in general. Without going into the details we are in close collaboration with several companies both on the engine side and the fuel."

But he cautions: "I think we have to keep in mind that although there are technical solutions available for burning ammonia there are naturally a few other considerations about whether it's a practical fuel. One again is infrastructure, second whether it's available in the right locations and the right quantity and thirdly is the matter of the price of the fuel. Naturally it's going to take some time before it scales up."

One major uncertainty that only receives a passing reference in the report is the current pandemic, although that is explored in greater depth in the broader Energy Transition Outlook report, published at the same time. It concludes that Covid-19 has brought forward peak CO_2 demand and transport use by five years and oil prices will never exceed 2019 levels again.

"When it comes to economic growth we expect that if and when a vaccine becomes available it will normalise and that's one of the reasons we didn't address it in particular," explains Ørbeck-Nilssen.

Longva adds: "We were halfway into the study and projections on seaborne trade when Covid hit us in March. But the report by Martin Stopford [considering the possible long term impact of Covid-19, see Editorial Comment, *TNA* May 2020] was one of the sources we used and tried to incorporate its impact into our thinking."

So what will be the turning point when the industry knows it is winning the race to decarbonise? "There is a tipping point where you go from testing, piloting and early commercial uptake to really accelerating. There's no way of knowing whether this will happen in one year or another. If you look at LNG we're almost there in terms of that tipping point, but it's that massive uptake which determines whether we win or not," says Longva.

"It's a difficult question but we're starting to see acceleration with some of the segments, like container vessels and some of the large oil tankers. But it really needs to pick up before we reach a tipping point. Although we tried and look at all the different scenarios in the report it's not possible to pinpoint one," concludes Ørbeck-Nilssen. *NA*

To access the Energy Transition Outlook reports visit: https://download.dnvgl.com/eto-2020-download

A two-pronged approach to decarbonising shipping is the only way

LNG ship fleet and bunkering capacity should grow as the world works to develop zero-emission fuels and meet decarbonisation goals, argues the LNG Marine Fuel Institute

To meet the International Maritime Organization's (IMO) greenhouse gas (GHG) emission targets of 2030 and 2050, the maritime industry must take a two pronged approach, which is to grow LNG ship fleet and bunkering capacity while the complex work to develop zero-emission fuels continues.

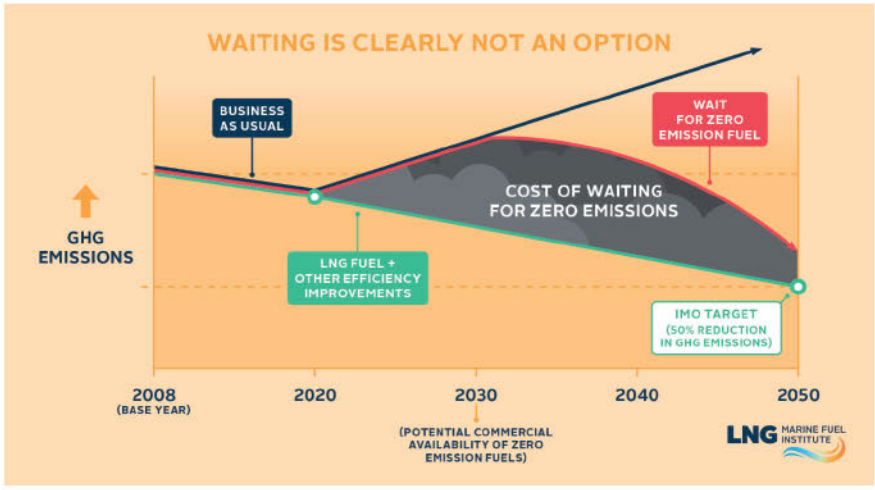
LNG is the best commercially available marine fuel today and will remain so in the near future. The commercial availability of zero-emission fuels are a decade or more away – doing nothing until they are available will result in needless GHG emissions.

This two-track approach is essential to maximising and accelerating shipping's reduction in GHG emissions. If we wait until zero-emission fuels are available, the marine industry will generate more GHG than necessary by missing the opportunity of the reduced emissions from LNG fuel. Likewise, LNG fuel is not the ultimate solution. Zero-emission fuels, when developed, will offer greater GHG reductions and make good business sense for many applications. It's not a question of doing one or the other.

As the best commercially available marine fuel currently available, LNG makes good business sense from an operating and capital investment standpoint for many applications. LNG's environmental footprint is significantly better than alternative fuels such as distillates and heavy fuel oils, having virtually no sulphur or particulate emission and significantly less nitrous oxide emission, resulting in substantially less local pollution around ports and port cities.

The life cycle of LNG

Life-cycle assessment of GHG emissions has found LNG to be up to 33% less than traditional heavy fuel oils, a performance which includes any methane slip along the life-cycle value chain. Combining LNG as a marine fuel with energy efficient design and operations can make a vessel complaint with IMO 2050 targets.



Commercial production of zero-emission fuels is a decade away, and will come too late to achieve IMO's reduction targets

While on a broader scale, zero emission fuels are crucial to the global fleet achieving the IMO targets, none are commercially available today and will not be for over a decade. The world is working unremittingly on determining the best technology and overcoming problems of scaling but, while there's no question commercial-scale production will be achieved, it will take time.

It's a similar situation to the development of a Covid-19 vaccine development – there's a lot of development happening across the globe, but it won't happen overnight. One report estimates there is US$1.4 trillion worth of work required to develop the technology and install the infrastructure for zero-emission fuels.

Hitting the IMO targets

If the maritime industry continues building vessels using distillate and HFO and wait for zero emission fuels, we won't achieve IMO GHG emission targets. Among the several barriers is the fact that shipyards don't have the capacity to build the required number of boats. It would also require scraping ships that are not at the end of their life, resulting in high costs.

The only way to maximise the reduction of maritime GHG emission and meet the IMO GHG emission targets is to grow LNG ship fleet and bunkering capacity, while the significant task of developing zero-emission fuel continues. A two-pronged approach that is a logical and best cost alternative for the maritime industry.

LNG MFI

Based in Australia, the LNG Marine Fuel Institute (LNG MFI) is an independent not-for-profit organisation established to enable LNG, the cleanest alternative available today, to be a primary fuel for marine transportation. *NA*

For further info visit: https://lng-mfi.org

Loading computers and the importance of continued innovation

Evolution in ship systems, as well as regulations, is the key to survival and safety at sea, especially with the advent of increasingly complex newbuild designs, says Jussi Siltanen, senior product manager of Safety Solutions at NAPA

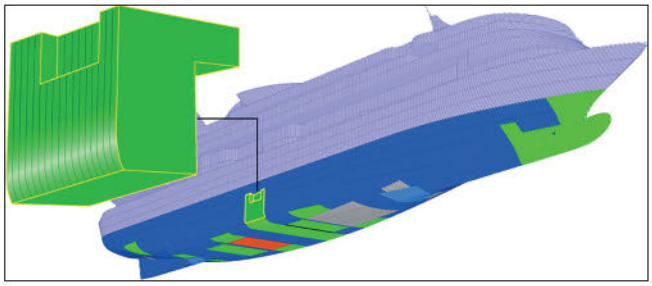
In 2019, guests totalling more than the population of Australia took a cruise, and across the commercial and passenger fleets another million and a half seafarers also took to the oceans last year. Ensuring their safety has long presented an enormous challenge to ship engineers and naval architects.

Today we rely heavily on technology to do that for us, but as ships venture closer to the poles and climate change makes our oceans more turbulent, the systems we depend upon to protect vessels and those onboard from harm must continue to evolve.

Vessel stability

Ship stability is one of the most important as well as complex safety factors at sea. Whilst, historically, a vessel's stability was mastered through a set of standard equations that were often tied to a specific system of measurement, the evolution of naval architecture and technological advancements has improved the way we manage ship stability. For example, Loading Computers are now recognised as the most effective way to simultaneously calculate a safe load for stable voyage conditions and method of loading vessels for maximum efficiency.

SOLAS regulation has evolved in line with these changes. It now requires that, for the purpose of providing operational information to the master for safe return to port after a flooding casualty, passenger ships constructed before 1 January 2014 must all have a secondary installation of a Loading Computer, which has the capabilities to calculate the damage condition, or additional shore-based support. The systems must be independent of each other and are required to ensure total safety for those onboard whilst out at sea.



Customised cruise ship version of NAPA's Loading Computer

The continued evolution of industry regulation to advance ship stability is hugely important as we see new, more complex vessel designs in the market and ensures we calculate stability more precisely.

Safety and efficiency – then and now

It was back in 1993 that we launched our first NAPA Loading Computer and since then have continued to develop the wide range of calculations available –including hydrostatics, intact stability, and ship longitudinal strength – and often well in advance of IMO regulation.

Drawing on elements of our NAPA Loading Computer software, which is used by almost all the major cruise lines, as well as the ferry, ro-ro, ro-pax, sto-ro and lo-lo operators, we have developed our most sophisticated stability solution yet, the NAPA Loading Computer Type 4. The solution further enhances safety in flooding emergencies and provides a vessel's master with more information to ensure a safe return to port (SRtP).

One of the fundamental updates to the software includes the calculation of damage stability associated with an actual loading condition and/or actual flooding cases, by using the direct application of user or sensor defined damage to enable SRtP.

In addition, and most significantly, the NAPA Loading Computer Type 4 also features updates to a vessel's automatic damage detection and incorporates the status of watertight doors, cross flooding, and escape routes into its modelling. Likewise, because the requirements from SOLAS – via IACS – have been implemented in class rules, damage stability functions and calculation results within a Type 4 Loading Computer are now subject to class approval. The NAPA Loading Computer Type 4 has also gained approval of damage stability functions and is IACS Type 4 and IMO compliant. With this in mind, and with our team aiming to be at the forefront of ensuring safety at sea, we will now only deliver Type 4 compliant software for passenger ships.

Evolution – the key to survival

Although the capabilities behind calculating and enabling ship stability have hugely advanced, from equations in a book to 3D calculation engines, the fundamental requirements for ship stability remain the same. The revised SOLAS and IACS regulation will make a major difference to passenger and crew safety on ferries, cruise liners, and other vessels, and will play an integral part in the continued enhancement of the shipping industry's safety standards. *NA*

Ensuring safety for the transportation of liquefied hydrogen

Having been already been applied to a ship construction project, ClassNK guidelines to support liquefied hydrogen transportation provide a significant roadmap towards a 'hydrogen society'

As a zero-emission fuel with availability around the world, hydrogen has the potential to transform modern society. Harnessing fuel cells as the power source for mobility, household, and industry as well as fuelling gas turbines are the most visible of society's growing initiatives to exploit hydrogen energy. But considerable work remains before a 'hydrogen society' can be supported on an industrial scale. One key component will be the ability for ships to carry large amounts of hydrogen worldwide.

From the viewpoint of transportation efficiency, practical options include the carriage of liquefied hydrogen in bulk, the organic chemical hydride method and deriving hydrogen from transported ammonia. In the latter two cases, transportation is possible using conventional chemical tankers or liquefied gas carriers according to IGC Code or other established safety requirements. The existing statutory framework has also been under development to cover the carriage of liquefied hydrogen, which is considered to be the most efficient method.

As liquefied hydrogen must be kept at temperatures below -253°C to maintain its liquid state under atmospheric pressure, it presents an even tougher handling and storage challenge at sea than LNG.

ClassNK responded to the expectations for liquefied hydrogen transportation provided in 2017, publishing a comprehensive set of 'Guidelines for Liquefied Hydrogen Carriers'. The guidelines took in the provisions of IMO's Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk, adopted by the Maritime Safety Committee (MSC) in 2016, and prescribed each item as a more specific requirement based on scenarios for possible accidents to ensure the safety of liquefied hydrogen transportation.

Launching ceremony of *Suiso Frontier* (courtesy of Kawasaki Heavy Industries, Ltd.)

The IMO Interim Recommendation was developed primarily based on a comparison of physical properties of methane as main components of LNG and liquefied hydrogen. Both are cryogenic and nontoxic, and both generate flammable high-pressure gas (see Table 1).

Hydrogen hazards

Comparing and examining the physical properties of hydrogen and methane, the key hazards related to liquefied hydrogen can be identified as:

1. Low ignition energy
2. Wider flammability range

Table 1: Comparison of Physical Properties of Hydrogen and Methane[1,2]

		Hydrogen	Methane
Boiling temperature	K	20.3	111.6
Liquid density	kg/m^3	70.8	422.5
Gas density (Air: 1.198)	kg/m^3	0.084	0.716
Viscosity Gas Liquid	g/cm.s x 10^{-6}	8.8	10.91
		13.49	116.79
Maximum burning velocity	m/s	3.15	0.385
Lower flammable limit	%vol	4.0	5.3
Upper flammable limit	%vol	75.0	17.0
Lower detonation limit	%vol	18.3	6.3
Upper detonation limit	%vol	59.0	13.5
Minimum ignition energy	mJ	0.017	0.274
Auto ignition temperature	°C	585	537

Suiso Frontier

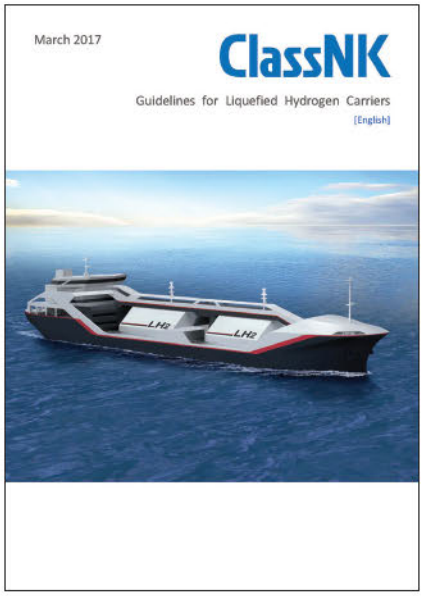
3. Low flame visibility during fires
4. High burning velocity, which may lead to detonations with shockwaves
5. Condensation (liquefaction) and coagulation (solidification) of gas constituting inert gas and air, which may lead to the formation of a low-temperature atmosphere with a high concentration of oxygen commonly known as a strong combustion aid if mixed with flammable gas such as hydrogen and also could result in clogging of pipes when solidified
6. High permeability
7. Low viscosity
8. Hydrogen embrittlement of materials for tank, piping and process equipment including welds

In view of those hazards, ClassNK's guidelines have provided special requirements for the following 19 areas:

1. Materials, welding of cargo tank, cargo process piping, pressure vessels and equipment
2. Thermal insulation and its materials of cargo tank, cargo process piping, pressure vessels and equipment
3. Vacuum insulation system for cargo containment system
4. Vacuum insulation system for cargo process piping, pressure vessels and equipment
5. Design, construction and testing of cargo tanks
6. Design, arrangement of cargo process piping, pressure vessels and equipment
7. Construction and testing of cargo process piping, pressure vessels and equipment
8. Pressure relief valves for cargo tanks
9. Vent systems for cargo containment
10. Cargo pressure / temperature control
11. Atmosphere control
12. Ventilation
13. Temperature, gas concentration measurement and hydrogen gas detection, fire detection
14. Measures against hydrogen fire
15. Personnel protection
16. Filling limits for cargo tanks
17. Operational procedures and operation manual
18. Risk assessment
19. In-service survey plans

For a risk assessment to be conducted in an exhaustive manner for the design specifications of an individual ship carrying liquefied hydrogen cargo, it must consider risks to persons onboard, the environment and the structural strength/integrity of the ship, with adequate countermeasures proposed. Key items, such as possible vent release scenarios, vent fires, gas diffusion analysis, boiling liquid, expanding vapour explosion, the possibility of explosions and detonations in enclosed compartments, and the loss of a single vacuum compartment in a vacuum insulation system must be specified in detail.

ClassNK's LH2 carrier guidelines, published in 2017



Susio Frontier

The guidelines developed by ClassNK in support of liquefied hydrogen transportation have already been applied in an actual project. They have been used as part of the world's first liquefied hydrogen carrier, built by Kawasaki Heavy Industries, Ltd for the CO_2-free Hydrogen Energy Supply-chain Technology Research Association (HySTRA). HySTRA is the consortium "established primarily to achieve technologies and carry out demonstration of everything from production of hydrogen via effective use of brown coal through to transportation and storage of said hydrogen, aimed at the cultivation of a CO_2-free hydrogen supply chain and its commercialisation". Named *Suiso Frontier*, the resulting vessel has a length overall of 116m and cargo tank capacity of approx. 1,250m^3 and was launched in December 2019. Its construction is expected to be completed by late 2020, according to KHI.

ClassNK received the application for classification survey during construction for this momentous vessel and carried out the verification and validation in line with its guidelines and applicable rules. In the meantime, ClassNK is updating the guidelines based on experience and knowledge acquired through design and construction, and as the ship approaches its operational phase, in its role of ensuring safety for the transportation of Liquefied Hydrogen by sea. *NA*

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1. ISO/TR 15916, Basic considerations for the safety of hydrogen systems (ISO)
2. National Institute of Standards and Technology (NIST) RefProp database

Brookes Bell expands its inhouse lab testing capabilities

The technical and scientific consultancy's new Liverpool facility will meet the growing demand for fuel testing, as well as state-of-the-art microscopy for forensic engineering investigations, writes Matthew Calveley

In July, Brookes Bell announced plans to develop a high-end laboratory to deliver comprehensive metallurgy, fuel testing, coating analysis and advanced non-destructive testing (NDT) facilities.

Building work on the new 8,000ft^2 facility in Bidston, near Liverpool, is already well underway and the new laboratory is expected to come online in November 2020. The £1.8million investment is part of the company's desire to increase the value-added, multi-disciplinary services it can offer clients and to push forward the technology used in inspections.

Initial progress at the new Brookes Bell's laboratory

The new test facility will house a fuel-testing analytical laboratory, reflecting the increase Brookes Bell is seeing in fuel-related investigations and claims. Poor quality fuel often leads to extensive and expensive machinery damage and catastrophic incidents. The facility will not only test fuel to ISO 8217 standards, to identify off-specification samples which will help to understand the causes and origins of fuel-related problems, but also will offer more complex investigative analyses, including GCMS (gas chromatography–mass spectrometry), FTIR (fourier-transform infrared spectroscopy) and ICP (inductively coupled plasma).

Other capabilities will include an advanced microscopy suite with state-of the-art digital microscopes and scanning electron microscopy, which can be utilised for a wide range of detailed forensic engineering investigations, metrology and paint analysis. High magnification examination of metal fragments and fracture surfaces can provide a lot of information about failure incidents and in the same manner small coating flakes can be inspected and analysed to determine the causes for a range of faults including blistering, detachment, cracking, rust formation and inadequate antifouling protection. Brookes Bell's inspection team can examine the properties of metals and materials, exploring the way they behave in different environments, such as when exposed to high temperature or when loaded, analysing the behaviour of the metal or material and determining how this interaction might have affected the component during service. In addition to laboratory testing, Brookes Bell has also enhanced its in-situ analysis and inspection capabilities with advanced portable techniques.

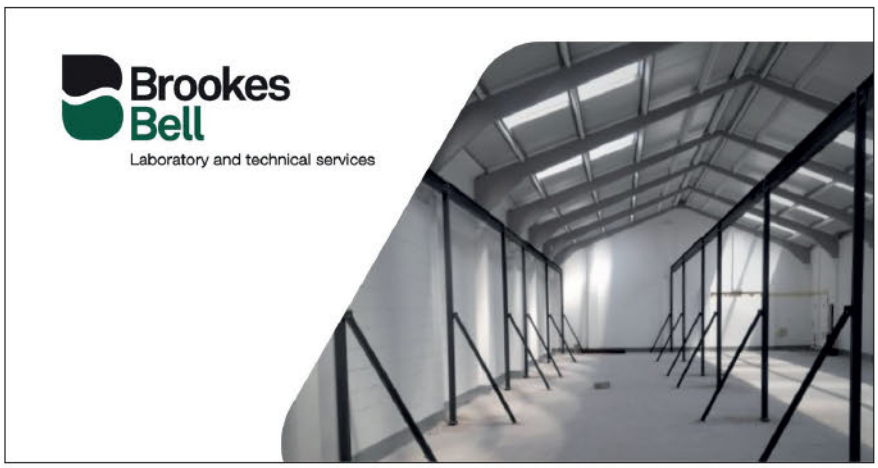
Matthew Calveley

Advancing testing technologies

Testing and inspection are the foundation of safety in any engineering structure. There are numerous methods of inspecting large structures prior to manufacture, during construction and through routine monitoring during operation. There is also a range of technologies available that can assist with this inspection too. In the event of failure, these same tools can be used to determine root causes in order to learn and to prevent future failures.

Although, in many cases, the purpose of testing is to determine whether a specific quality or standard is met, the ultimate purpose of an investigation is to ensure functionality and safety. The methods used for testing an engineering structure can range from analytical chemistry, such as fuel analysis and metallurgy, through to physics in the form of non-destructive testing (NDT) techniques. Based on their own field experience, the team at Brookes Bell is keen to drive forward the advances in testing technology and to make them more widely adopted so they can be applied to more investigations.

Initial progress at the new Brookes Bell's laboratory



As an example, welding is a fundamental process used in large scale fabrication projects, such as ship construction, and the quality of the welds is critical to the overall strength and integrity of the overall structure. The failure of a weld in a critical location can result in sudden, catastrophic failure, loss of a ship and loss of life.

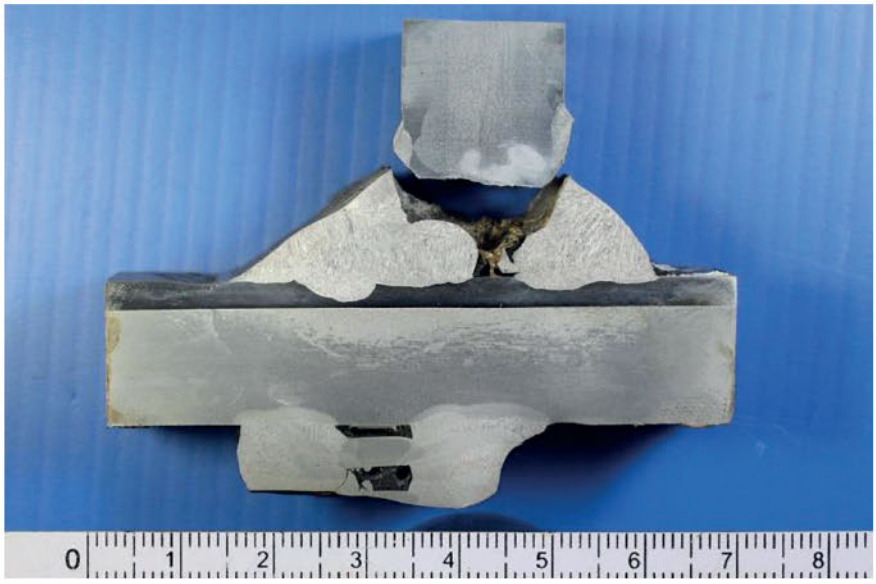
There are of course well-established procedures, rules and checks in place to ensure the quality and integrity of welds. There is (hopefully) a base line of training and qualification/certification available for welders to ensure they are well equipped and competent in their roles. However, even with the most stringent of procedures and quality control – things inevitably go wrong. It is the ability to identify and rectify these defects (particularly in critical areas) through testing and inspection that can ensure the integrity of the structure. This is the foundation of a sound quality system.

Identifying defects

There is a complex combination of production processes involved before a single weld is even produced including preparation for cutting, steel plate cutting processes, formation of hull plates and stiffeners and the associated transport, and assembling of plates and profile (pre-erection joints and erection joints). Control of these processes all contribute to the final quality of the weld and require careful attention to detail. However, a proportion of defects and imperfections are unavoidable in large-scale fabrication projects. The consequence of not identifying these defects is well known and can even be catastrophic.

NDT helps to identify defects before they result in failure

The conventional NDT used to identify defects in shipbuilding may include simple surface techniques such as Magnetic Particle Testing (MT) and Liquid Penetrant Testing (PT), or volumetric methods such as Ultrasonic Testing (UT). These methods may only capture a small amount of data available but there are a range of other techniques, such as Eddy Current array (ECA), Phased Array Ultrasonic Testing (PAUT) and Time of Flight Diffraction (TOFD), which can capture and record a much greater amount of detail. In addition, these more advanced methods allow for the integration of software which can more clearly describe and report the location of defects.



NDT helps to identify defects before they result in failure

Corrosion mapping using Eddy Current technology

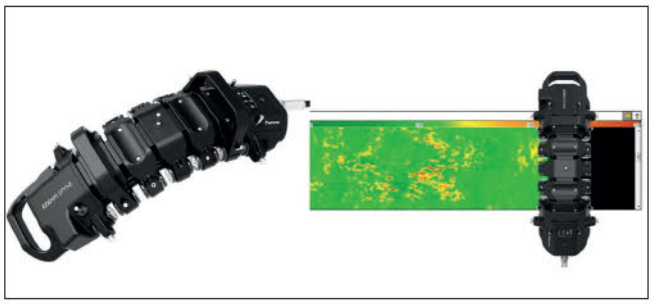
Advanced NDT methods are also useful for corrosion mapping and monitoring solutions and where inspection is inhibited by the presence of thick coatings such as composite cladding, teak or Bolidt deck. Brookes Bell is developing a range of bespoke and innovate in-situ applications for this particular application. In this regard, Brookes Bell is looking to apply their expertise and technology to the full life cycle of engineering structures – whether that is during construction, routine inspection or at the point of failure.

Marine inspections requiring forensic level analysis are usually multi-discipline, working with engineers and master mariners, to apply their experience and knowledge to the situation. As investigations become more and more complicated, more advanced skills and equipment are needed to investigate failures. The application of the right technology and analysis can enhance this ability to investigate and ensures that Brookes Bell is at the forefront of both laboratory testing and analysis in the field.

About the author

Matthew Calveley is senior metallurgist at Brookes Bell. He has an honours' degree in forensic engineering, an MSc in Corrosion and has carried out marine and industrial based failure investigations since 2008. Prior to joining Brookes Bell in 2010, he was a process metallurgist working with corrosion resistant alloys which were predominantly used in the oil and gas sector. Matthew specialises in failure as a result of corrosion. *NA*

Corrosion mapping using Eddy Current technology



SSI: 30 years of shipbuilding software

Today's shipbuilding software has come a long way from the CAD programs of three decades ago. Canadian-headquartered SSI has been around for much of that time, thanks in part to its adaptability

ShipConstructor Software Inc (SSI) has seen a lot of changes since it was formed in 1990 (as Albacore Research Ltd) by Rolf Oetter as an outgrowth of masters research he'd been undertaking at the University of Victoria, Canada. Oetter recognised early on that not only did shipbuilding need to modernise and adopt innovations, but also that 'shipbuilding specific' engineering software would benefit by being compatible with other tools such as AutoCAD and SQL servers to allow for integration.

After some early success with its ShipCAM program, deployed on designs for workboats and superyachts, in 1997 the company released the first version of its ShipConstructor tool, which in the following years would evolve into a complete shipbuilding engineering solution. Over the past 20 years, the company has continued to expand its reach into Asia, the US and Europe with an impressive array of projects and partnerships.

But according to Darren Larkins, SSI's current joint CEO, that original commitment to developing a versatile solution which 'plays' properly with other tools has meant the company is well positioned for the multi-platform approach that's become commonplace today.

Larkins tells *TNA*: "Ten years ago, everyone was searching for a unicorn solution – one platform from one vendor that could do it all from start to finish. Unfortunately for those who went down that route, the promised simplicity of a monolithic solution never appeared.

"The industry has definitely moved away from that towards the realistic idea of a 'platform of platforms' ecosystem. With platform of platforms, each piece of your enterprise architecture can connect to, push and pull from, and sync with every other piece. This is the only way to ensure that your technology is adapting to your business and not the other way around."

SSI's joint CEOs Denis Morais (left) and Darren Larkins

That means ensuring that the engineering data created can be used wherever it is needed. It also increasingly extends to making it possible for every department or stakeholder to access the same source of 'truth' in a format they can consume and make sense of. "We've embraced this philosophy from the beginning. As more shipyards embrace seamless integration as the way forward, we can step in and reduce the amount of time it takes to make data useful."

That's not to say the company wasn't guilty of making some of those same mistakes in its early years. "SSI was initially one of those best-of-breed companies focused on the engineering needs of shipbuilders, but we recognised the dilemma so many were struggling with: go with the monolithic jack-of-all-trades master-of-none approach that has some limited integration or cobble together a best-of-breed 'shipbuilding solution' and struggle with the integration. Our goal is always to allow shipbuilders to work with whatever software platforms they prefer and make it possible for them to work together in what we call a synchronised shipyard."

Larkins notes that shipbuilders, particularly those in North America and Europe, have embraced that the latest technical innovations can help them build better and more sophisticated ships. However, while that has meant the amount of data available within an organisation has increased exponentially, turning that data into a useable form for those who might need to make sense of it has lagged behind. While SSI has remained focused on helping shipbuilders concentrate on shipbuilding, continually expanding the functionality of its software, information generated within that operating environment has been readily accessible to partners, clients and even rivals.

"We've seen a growing interest from other companies that have specialised solutions. As we became more ambitious about the levels of integration we could achieve, it was clear that there was a growing demand for an easier way to consume and distribute information at the item and part level."

It led the company to develop a creation framework known as Genesis, which allows partners to create SSI native and intelligent parts outside of the traditional SSI user CAD environment.

"It's just one more piece of the puzzle that allows our partners to create a robust integration quickly, blurring the boundary between applications. For our clients, that means they are no longer the ones having to worry about integrating information or making it usable across their organisation," says Larkins.

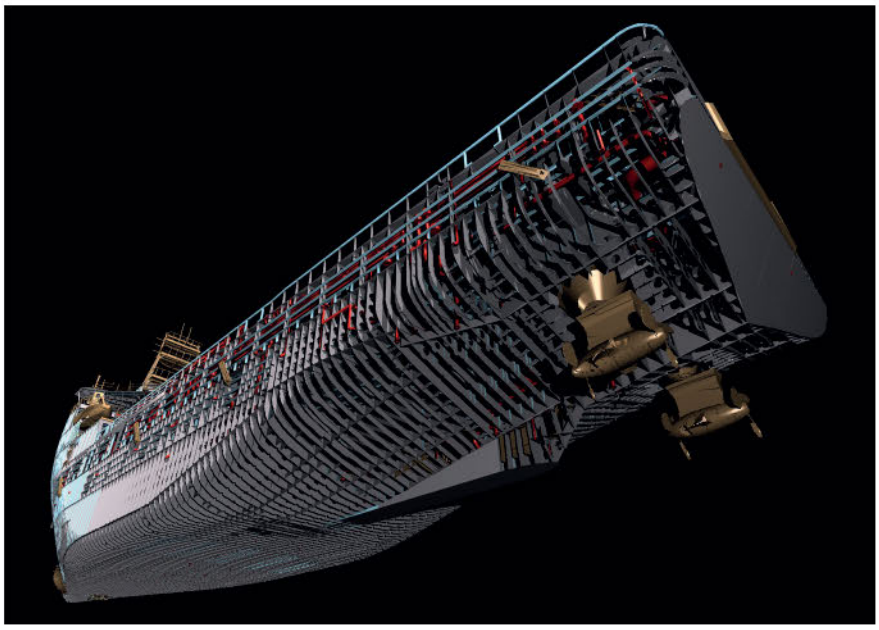
Synchronised organisations

Denis Morias, the other half of SSI's executive leadership, comments that clients are becoming ever-more specific in terms of their requirements and the kind of functionality they demand. "Shipbuilders are more technically sophisticated than ever, which helps, but most importantly, they have a better understanding of the business goals and transformation they want to achieve.

"Instead of just improving what they already do at a departmental level, they recognise that digitising existing processes can be leveraged across and throughout the overall organisation. They're able to help look at all the technology available and every current process and see a way forward toward a truly synchronised organisation."

Morais says that while currently the focus and ambition for shipbuilding projects are on effective integration from concept to launch, there are huge benefits to be gained by owner-operators spinning out this digitisation into product lifecycle management (PLM). "It's very easy to imagine a well-maintained Digital Twin of all vessels within a fleet, which in turn has huge ramifications on maintenance all the way through to decommissioning. This is the future for the business of shipbuilding."

SSI, and Morais in particular, were somewhat ahead of the curve when it came to talking about concepts such as Digital Twins, which has come to be common parlance across the industry. However, he believes that more often than not the tendency towards compartmentalising means that what's in effect is often "a portion of an overall Digital Twin".



ShipConstructor, SSI's flagship engineering tool, was first launched in 1997

"For example, they are in place for some sub-assets but are not able to use the contained information to feed the rest of the organisation. So, we do hear a lot about access, but most often, it's because there's not enough, or it's the wrong type of access."

He adds that the tendency towards 'silos' within organisations, and the inability to view the project or asset as a whole, is one of the issues the Digital Twin concept was supposed to alleviate, but when work from one team can't be used by another then those benefits aren't being realised. "So breaking down those silos and using the information that the Digital Twin is now housing across every department has been the largest challenge. Embracing this idea puts organisations at a considerable advantage."

Innovation culture

So, from the perspective of a service provider, what should the industry be doing differently? Morais believes the biggest elephant in the room currently is the mindset and culture within shipbuilding. "While it's improving each year, right now, there is still no widespread culture of innovation. Without one, the companies in shipbuilding are not going to be able to leverage the great new technologies that are being uncovered and developed each day."

"There's never going to be a one-size-fits-all approach to this, but we're seeing great results when leadership is aligned that changing their culture will result in a better, more resilient business and puts those principles into action. That is the only way that culture can really change.

"One of the keys to that shift is embracing the idea that it is okay to fail. Without that, there's no chance of change, no matter what you try to communicate with your team. There is already so much proof that adapting our culture is one of the keys to overcoming tomorrow's challenges."

And Morais thinks the company is perfectly positioned at the nexus of what shipbuilding is, what it is becoming, and the technology that will empower that. "Managing information at the scale of shipbuilding requires an approach that simplifies the complexity of shipbuilding's specific challenges like sister ships. But what we've come to realise is that, where shipbuilding is concerned, not all PLMs are made equally. The way shipyards actually function must be considered.

"We're hard at work developing and refining our Shipbuilding PLM solution to solve that complex problem. We've already seen great success at helping clients get control over their data in this way, and made it possible for better, more informed decision-making to emerge across the organisation." *NA*

COMPIT 2020: finding human solutions for the digital age

Nick Danese offers his thoughts on the prevailing themes of this year's COMPIT, which took place – with some remote participation – in Italy in August

The glorious setting on the hills just north of Siena of the Certosa di Pontignano made everyone forget about the nuisances imposed by our new tag-along friend, the Covid-19 virus. COMPIT 2020 took place from 17-19 August, a time of holiday for some (who nevertheless made it to the conference) and a time of masks for all.

Some presentations were delivered digitally, marking the beginning of a new era as poignantly noted by Plowman in 'Digital Maritime Training in Covid-19 times'. Interestingly, very much like in the world of autonomous ships, second thoughts are surfacing about the efficiency and effectiveness of technology when it is too devoid of physical human presence. Although culture is a strong qualifier in this respect, chats at the coffee machine remain crucial for some in order to allow cross-pollination and team creativity to run their courses. There's possibly not much room for cyborgs here, at least not yet, although 'Mariner 4.0' human digital twins are being considered.

Similar thoughts about how important people really are, and how required their presence is, was taken up by several authors. Eriksen pointed out that if something goes wrong on an unmanned autonomous ship there will be no-one around to fix it, let alone carrying out maintenance at sea that will otherwise result in longer port stops. 'On board human operators: liabilities or assets?' also explores the paradigm underlying the assessment of the relative merits of humans and AI processes when it comes to safe navigation and collision avoidance. It can be easily construed that if Artificial Intelligence (AI) were better at predicting and avoiding clear-cut dangerous situations, humans might still have the upper hand when it comes to recognising a potential crisis very early on and getting out of hot waters by taking unconventional actions, factors not considered very much in current accident statistics.

Despite the pandemic many delegates made the trip to Tuscany to attend in person

The limits of computing

As Volker Bertram noted in his COMPIT Preview (see *TNA*, March 2020), it looks like man and machine make a powerful team and each will excel in some of the many concurrent and inherently interlaced processes that compose the world, marine included. In this respect, Bertram tells how the recent years' blitz forward to Artificial Intelligence, Computational Fluid Dynamics (CFD) technology, etc. left behind more than a few solid cornerstones devised over time and has not (yet) placed in a realistic perspective the absolutes produced by high-tech algorithms.

'Ship Hull Optimisation – An Attempt to Determine Position and Course of the State of the Art' resurrects the asymmetric stern that optimises flow into the propeller, notes how rudder and propeller are not taken into account enough when applying CFD to stern and wake, highlights the forgotten obvious point that ships hulls are 'optimised' for calm water resistance while in reality a ship will be pushing through high-resistance wavy seas more than not, that true sisterships will exhibit easily measurable differences in performance, etc..

Reason and pragmatism are found in several other papers. For example, the issue of what makes an optimisation process valid is discussed by Diez et al. in 'Adapt, Adapt, Adapt: Recent Trends in Multi-Fidelity Digital Modelling for Marine Engineering' where it clearly pointed out that as the quality of hypotheses and base-data will influence the quality of the results of any process, self-teaching ones included, in certain circumstances a less sophisticated approach might yield a higher quality result than a highly complex one.

In one of his blogs, COMPIT veteran Denis Morais noted that the "transition to

the concurrent dynamic workflow providing very high frequency information [traffic] will have the same challenges as when we moved from a purely linear workflow to a static concurrent workflow". To expand that thought, as automation and AI increase their footprint in process-to-process interaction more will happen without any human intervention and, corollary, without humans necessarily knowing.

Building better twins

This requires ever higher quality, robust and more pertinent digital twins which must be developed during and cater to the very earliest phases of design and be maintained thereafter. Perez Fernandez et al. discussed "How to Achieve Smart Ship Design through the Industry 4.0", advocating that "CAD tools [must] be prepared with specific characteristics to handle the information. This new ecosystem, opened, incorporating the new trend of technology but adapted to the specific environment of shipbuilding, will be the Smart Ship".

Perez Fernandez went on to define the clear link between a multi-author CAD-type initial digital twin – effectively the digital description of every physical component of the ship – to the operational model, from predicted to effective, that must incorporate Big Data in general. The learning curve behind evolving predicted nominal performance to the effective field-measured performance needed to improve the former and feed predictive maintenance processes, AI learning processes, etc. is supported by the massive implementation of Internet of Things (IoT) connectivity. Accurate and robust digital twins are core to ship operation, maintenance, repair and retrofit, from correct as-built structural 3D models and plans to the historical data of machinery collected over time.

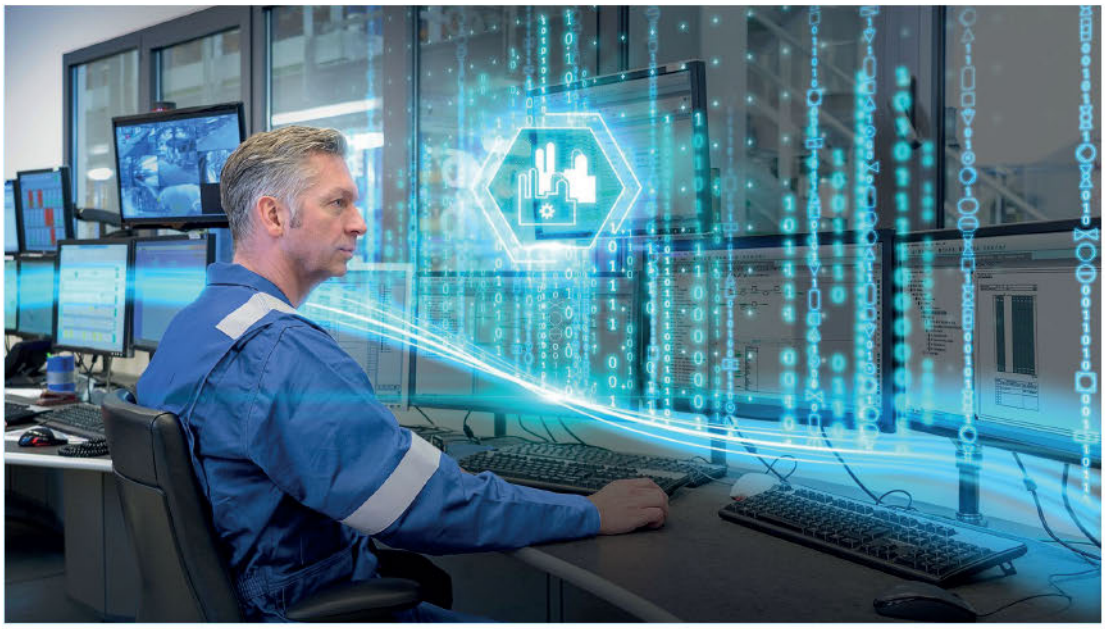
Worthy of notice, Perez Fernandez suggested that "we are running out of conventional approaches to make ships more efficient" and that the Industry 4.0 paradigm represents an opportunity to "obtain quantum leaps in improving performance". Moreover, "horizontal platform" are identified as "key to success" (Taylor, 2016). "the mentioned platform . . . is a set of interconnected applications which share the same data about the product", data which will include both design and expected performance values and parameters. Semantics aside, while platforms of platforms have been advocated before, partaking in multi-player efforts and sharing data, parameters and information with commercial competitors has not yet won everyone's heart and, in fact, one-vendor-does-it all "solutions" are still being developed.

That different players, be they people, processes, software or machines, do things differently and some better than others must no longer hamper acceptance that the true yet never total overlap and redundancy of many commercial software products can be built into the collaborative horizontal platform of platforms.

Humans before hype

Danese reviewed existing software products that already constitute collaborative horizontal platforms in the marine design world but pointed out that these multi-vendor realities are as common as they are unexploited by those who have all the tools available to them. Culture and fear of change remain major obstacles, and people are identified as a critical component to any 'platform of platforms' ecosystem. 'Platform of Platforms and Symbiotic Digital Twins: Real Life Practical Examples and a Vision for the Future' discusses whether technology really benefits from great focus which generates empty hype, while the human factor, so clearly identified by Plowman in training, is largely ignored. Distributed, collaborative work shines a spotlight onto the dilemma of sharing data and information not just among software programs but also among people of different cultures.

This requires not just exchangeable and somewhat universal data sets, but also an understanding of how they will be used and in pursuit of which goals, a very human component of the overall process often forgotten or the victim of the incorrect assumption that there is one correct way to do something . The concept that every



Increased automation and AI demands better digital twins. Source: Siemens

Studies presented included papers on Augmented Reality. Source: Cadmatic

participant in every process is an author underpins the use of what have been traditionally considered engineering tools in processes and activities so far considered as unrelated. For example, the CAD model used to constitute even early performance digital twins will also serve the sales process (once rendered), help ascertain safety and operational characteristics, etc.

Unified data models

More on sharing data and information across the horizontal platform, Zerbst et al. presented the fruits of a significant research and development effort in creating a system agnostic bridge between vastly different CAD-type software tools commonly used in marine design and shipyards. A loud first in our industry, 'How to Achieve Data Integrity in Ship Design Through Unified Data Models' presents a groundbreaking implementation of the "definition model" paradigm that will contribute so much to the growth of the backbone of the horizontal platform made up of symbiotic digital twins.

The difficulty so elegantly overcome by this work resides greatly in creating an engine capable of analysing and mapping the inherent characteristics and logical architecture of a given CAD-type model, including underlying intelligence and use of metadata. The resulting (Business Interface for Business Objects) BIBO unified data model collects geometrical, relational and associative data in its simplest representation while maintaining all the defining and other connections built into the original model.

This allows re-use of both geometry and logic in reconstructing identical models based on different data model architectures and employing different intelligence and mapping schemas. Already in its early implementation stages, the OpenPDM SHIP software tool allows transfer of structure models between the environments of major players such as NAPA Steel, Aveva, SSI ShipConstructor, Siemens TeamCenter, etc. Zerbst shows real-life case studies and very clearly illustrates the importance of the vendor-agnostic ShipXML model at the base of all the connectors to just about any vendor-specific destination.

The advance of ASVs

Another innovative research effort is discussed in 'Evolution of Autonomous Surface Vehicles' by Bibuli et al. In more ways than one, the Autonomous Surface Vehicle (ASV) developed, built and field tested collects all the advances reviewed so far. The small, very lightweight catamaran exhibits a remarkable combination of autonomous yet interacting digital twins. AI-driven learning using a newly developed strategy produced very dependable and accurate routing, full interchangeability of sensors in standard casings required a very flexible IoT platform, the flush multidirectional horizontal pumps allow navigation over hard obstacles, the resilient and very lightweight foam hulls withstand impact undamaged, and there is room left for additional edge computing to enhance data pre-processing and reduce the amount of data transmitted back to shore. The ASV was designed and built using components from several vendors and possible future variants were built into the design thereby effectively constituting an integrated horizontal platform.

Finally, a number of interesting studies were presented in the field of AI, Autonomous Vessels (manned and unmanned), Virtual and Augmented Reality (VR and AR), CFD research into hull optimisation and current trends, inception of technological support to human surveying in teaching and operation, the employment of drones in hull surveys, training using simulators, the application of VR and AR in carrying out maintenance and, a vast field in itself, the application of machine learning to design, fabrication and operation of marine vehicles.

The COMPIT 2020 award was attributed to Rodrigo Perez Fernandez in recognition of his contribution to a vision of an innovative marine industry of the future.

Food and drink are abundant and easy to appreciate in Tuscany, COMPIT 2020 lacked neither. The majestic Certosa di Pontignano will be replaced by the epitomic "The Wolfsburg" venue in Mülheim an der Ruhr for COMPIT 2021 and expectations are already high for local fare and best-in-Germany beer. *NA*

Trim Optimisation: using NavCad for prediction confidence

There are cheaper, less time consuming alternatives to CFD surrogate models, writes HydroComp's Don MacPherson

One tool in an operator's hunt for fuel reduction is trim optimisation. Simply put, this is the setting of a ship on a waterline – different from its design waterline – that will offer a reduction in power demand and fuel consumption. It is an interesting proposition, but one that must be undertaken by both operators and designers with an appreciation for the constraints of a trimmed operation, as well as the uncertainties in the prediction of power under trimmed conditions.

The first question that I would ask is "what compromises are being made if I run trimmed?" Ship operation is more than just the economics of fuel consumption. Other considerations that may prohibit trimmed operation include:

- Reduction in visibility
- Emergence of the propeller
- Seakeeping, motions, or shipped water on deck
- Underkeel clearance
- Hull loading and strength

Once it has been satisfied that these restrictions can be met, only then will it make sense to look into benefits of trimmed operation and find an 'optimum trim'. Let me first propose that there is no such thing as 'optimum' in naval architecture. Everything is a compromise, but we definitely can find what is 'better'.

Propulsor efficiency

In most cases, trim optimisation studies focus on the reduction in ship resistance, which makes sense given that this is the principal demand on the system. Power and fuel are the response to that demand. However, there can be variations in propulsor efficiency with trimmed operation (particularly with bow down operation) that should be investigated as part of the study using a system tool such as NavCad for full Vessel-Propulsor-Drive prediction of fuel.

Many trim optimisation studies are based on CFD 'surrogate models' whereby a matrix of loadings and trims are calculated to provide a way to interpolate a prediction. As you might expect, this can be a costly and time-consuming set of calculations, as many combinations of draft, trim, and speed are needed to create the matrix of results.

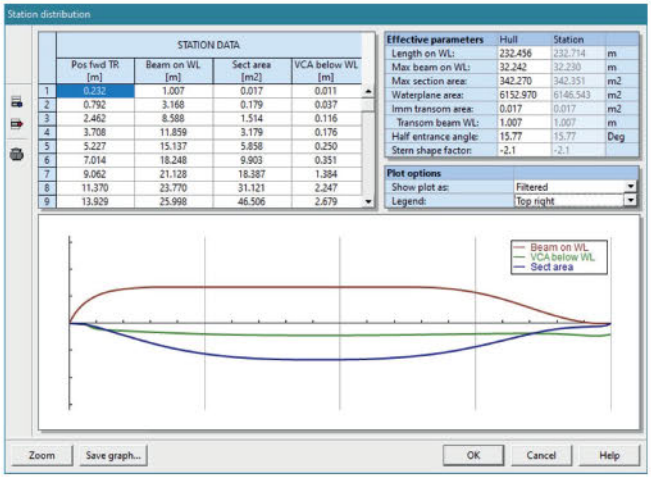


Figure 1 – "2D" data used for ADVM

That said, it is a strategic calculation that should need to be conducted just once. Let me also note that confidence in complex analytical computations can be masked by a lack of benchmarking or validation, and CFD calculations are no exception. For example, let me quote opposing conclusions from two published CFD studies of trim optimisation for the well-known KRISO Container Ship (KCS):

1. "The effect on resistance is varying during stern trim and optimum trim point is 0.02m trim by stern." (This is about 0.15 degrees for about a 2.2% drag reduction.)
2. "The free model can accurately predict the 1% reduction in total resistance when the ship is trimmed 0.25 degree by bow."

Not a great confidence builder... so let's then consider the benefit of reduced-order calculations that have some semi-empirical basis, again such as those available in NavCad. Often called 1D and 2D methods, parametric methods (1D) and NavCad's Analytical Distributed Volume Method (ADVM, a 2D method) provide efficient alternatives or companions to CFD (3D). Can these methods provide a sufficiently accurate option for prediction of trimmed operation? Well, yes and no.

Parametric (1D) methods are generally unsuitable for trim optimisation. This is not surprising, as these methods are based on dimensional analysis of ships at their design waterline condition. Trimming a vessel distorts its parameters so that they fall outside the scope of the original data sets. (There are a few parametric methods that do consider stern-trimmed ballasted orientations, but these were for obsolete merchant cargo ship hull forms without bulbs and with simple stern shapes, so they do not represent contemporary vessels.)

NavCad's ADVM (2D) method utilises 3D hull CAD geometry (like CFD), but is able to provide predictions at a fraction of the resources required for CFD. It can be manipulated in different ways to account for sinkage and trim, which is critical for ships with flat transom sterns that may become immersed. While the ADVM method is certainly not a replacement for the many tasks and analyses that CFD can offer, it does provide a strong and cost-effective option for trim studies or benchmarking CFD.

For example, in the plot below of KSC

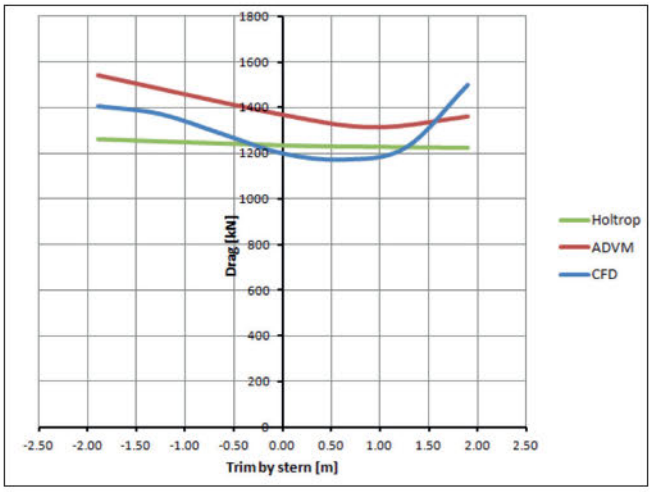


Figure 2 – Predictions for the KCS

predictions, we see that the ADVM method and CFD produced very similar qualitative outcomes. (Note that the ADVM did over-predict resistance, which we believe is due to an over-estimation of the form contribution in the method. A new viscous form drag model is under development to improve this for KCS-type vessels.) The parametric method (Holtrop) demonstrated good correlation to CFD at the design (zero trim) condition, but showed very little influence of trim on resistance.

Using a reduced-order calculation – such as the ADVM method in NavCad 2020 – is essential to an initial assessment of the benefits of trimmed operation and to narrow the scope of the design space if proceeding with higher-order CFD studies. Then the predicted resistance figures, whether by NavCad's internal methods (such as ADVM) or external methods (such as CFD), can be extended to full fuel prediction as part of its Vessel-Propulsor-Drive system simulation. *NA*

About the author

Donald MacPherson is an internationally recognised specialist in applied hydrodynamics, with particular emphasis on the design of propulsors and the numerical forecasting of vessel and propulsor performance. He is the co-founder and technical director of HydroComp.

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The effects of hull deformation on draught survey

Multiple points of deformation can compromise the hogging and sagging assumptions of draught survey calculations, but Nicolas Bialystocki, a marine engineer at Antares Maritime Services, believes he has developed a possible solution

The determination of vessel's displacement is fundamental for commercial reasons in order to accurately calculate the cargo being loaded or unloaded, and this is measured in the process known as Draught Survey.

The measurements of draughts are normally in six locations: the aft, forward and midship in each port and starboard side of the vessel's hull. These measurements are used to carry out various corrections in order to determine the displacement.

One crucial correction is that of hull deformation or hogging/sagging correction, and a principal assumption is that the shape of the hull in terms of draughts along the length of the vessel is parabolic.

Correction of measured drafts for Hog and Sag

As a consequence of the parabolic hull behaviour assumption, most surveyors use the Quarter Mean Draft, or the Mean of Means (MoM), as a correction due to hull deflection, using the following formulas:

(1) $MoM = \frac{DAP+6DM+DFP}{8}$

(for fine lined vessel)

(2) $MoM = \frac{DAP+4DM+DFP}{6}$

(for fuller form vessel and box shape)

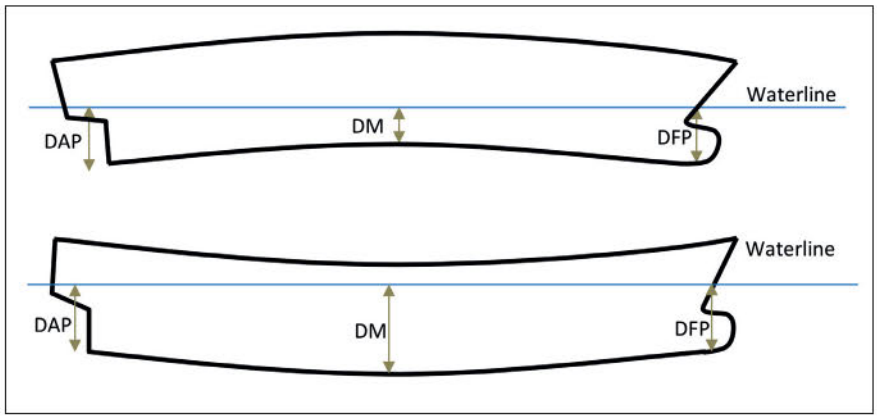


Figure 1: Hogging (top sketch) and sagging (bottom sketch) conditions

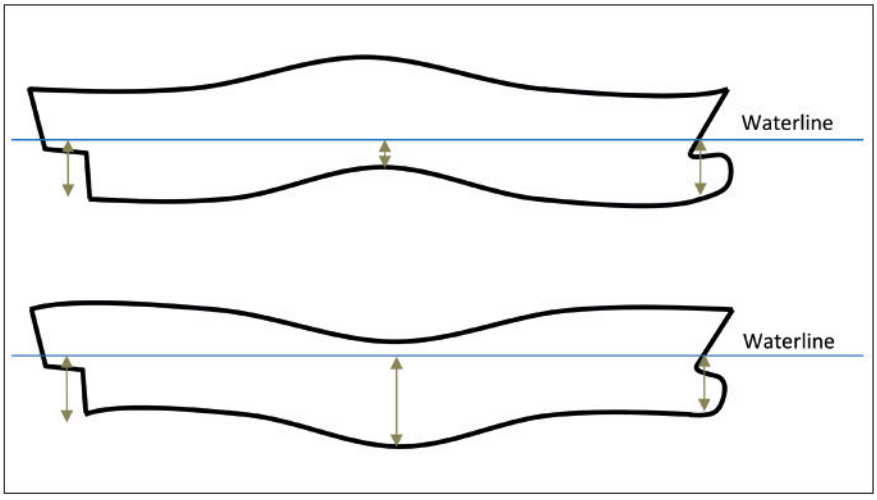


Figure 2: Double sagging (top sketch) and double hogging (bottom sketch) conditions

Ziha, K. in his paper 'Displacement of a Deflected Ship Hull', argues that the above formulas are generic, and a ship specific correction formula was elaborated based on hydrostatic information only.

Nevertheless, as the vessel becomes larger, the biggest challenge is taking into consideration whether a vessel might be in a condition as having its hull deflected in several points, not just in one point (midship). In other words the hull has multiple deflections as shown in Figure 2.

Pitfalls of the standard correction

This parabolic hull assumption is used as common practice by draught surveyors. However, in many cases there are large deviations in cargo quantity either plus or minus, depending on the condition of the vessel, which can be as much as up to 1,200tonnes for Capesize bulk carriers.

The reality, for many vessels the hull has Multiple Points of Deformations (MPoD), rather than a Single one (SPoD).

In the double sagging condition, the real MoM would be larger than the MoM calculated by the parabolic hull shape assumption. This situation may occur for instance with loading in the forward and aft hold, while the central hold remains empty. In this scenario an initial draught survey may indicate lack of cargo.

On the other hand, in the double hogging condition, the real MoM would be smaller than the MoM calculated by the parabolic hull shape assumption.

Forward Draught Marks read during Draught Survey

This situation may occur at heavy ballast condition, where in a final draught survey after completion of cargo unloading, the surveyor may again find missing cargo.

Any solutions?

The majority of published guidelines, papers and articles concerning the importance of correctly measuring draughts for the effects of hull deformation struggle to find a solution for the increasing number of vessels with MPoD.

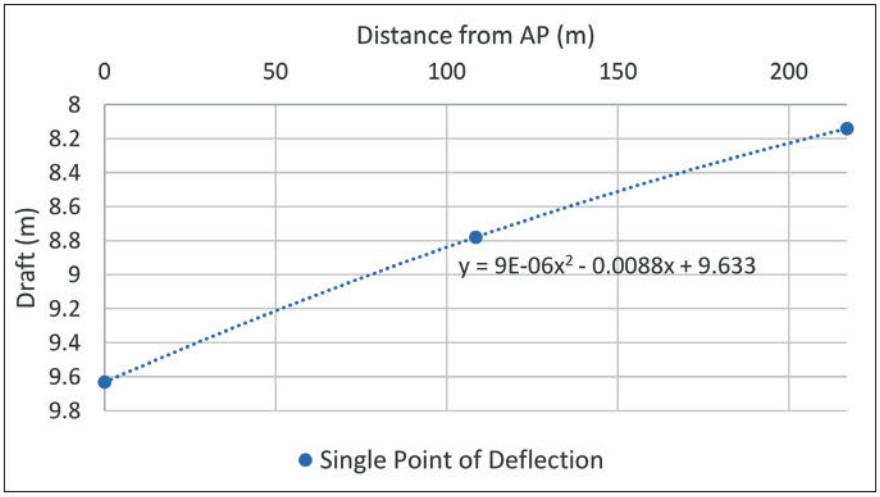
Some capesize owners have fitted laser instrumentation onboard the vessel in order for a surveyor to check the draught at several points along vessel's length, and presumably establish a more accurate MoM. But this solution is still far from being widespread, and surveyors find themselves in situations where they struggle to identify the reason for large cargo quantity deviations.

Other recommendation includes welding of draught marks at the quarter and three-quarter points of the ship's length on both the port and starboard side. However, hitherto few vessels have adopted this solution.

In cases where the multiple deflections are caused by the heavy ballast condition of a vessel, another recommendation commonly advocated is to de-ballast for the purposes of the survey, and then ballast again prior to sailing. But the author sees this solution as being impractical.

It should also be remembered that a vessel may be in a multiple deflection condition just before leaving a port, placing the surveyor in a difficult position, in which they have to complete the survey as fast as possible without compromising their professional standards.

Figure 3: Parabolic hull shape of a use case



Proposed algorithm

In view of the above circumstances, the author has developed an algorithm that will assist the draught surveyor in carrying out deflection correction effectively and help to obtain the most accurate results in cases of MPoD.

The first step is identifying those vessels which are suspected to have multiple deflection points along their length, and larger vessels are our first candidates. The United Nations recommendation for data manual for draught surveys is that vessels above 200m in length should have additional draught marks, thus these are the primary suspects.

Secondly are those vessels which are at loading conditions that are not homogenous along the length of the vessel, including vessels with alternate cargos, vessels with partially loaded holds, vessels with substantial difference in cargo weight in holds and vessels at heavy ballast condition.

The basic industry-recognised draught survey procedure is not changed, however, several steps are added to encompass hull shapes with MPoD.

Step 1: The parabolic line

In this step, after measurements of drafts in 6 positions, and correcting to the perpendiculars, each aft, midship and forward drafts are drawn in a computer program and the parabola equation is found. See example in Figure 3.

Step 2: The intermediate deflections

This step includes the estimated draft at 1/4 LBP and at 3/4 LBP, using the equation of step No. 1. Thereafter, the intermediate hog/sag between aft perpendicular and midship and between midship and the forward perpendicular, are calculated, as per Table 1 and equations.

$$(1)\ Def_{1/4L} = D^{Par}_{1/4L} - \left(\frac{DAP+DM}{2}\right)$$

$$(2)\ Def_{3/4L} = D^{Par}_{3/4L} - \left(\frac{DM+DFP}{2}\right)$$

Step 3: The assumption

This step is the most crucial one during the process, herewith suggested, because it nulls the SPoD or parabolic assumption, and instead it introduces the MPoD new assumption. In practice it is being carried

	Draft (Parabolic) (m)	Distance from AP (m)
AP	DAP (M)	0.00
¼ LBP	D1/4LPar (C-SPoD)	¼ LBP
Midship	DM (M)	½ LBP
¾ LBP	D3/4LPar (C-SPoD)	¾ LBP
FP	DFP (M)	LBP

Table 1: Drafts under SPoD assumption. Note that marking of deflection is negative (-) for hog and positive (+) for sage, and (M) denotes Measured and (C) Calculated

	Draft (MPoD) (m)	Distance from AP (m)
AP	DAP (M)	0.00
¼ LBP	D1/4L (C-MPoD)	¼ LBP
Midship	DM (M)	½ LBP
¾ LBP	D3/4L (C-MPoD)	¾ LBP
FP	DFP (M)	LBP

Table 2: Drafts under MPoD assumption

out by changing the sign of the deflection from positive to negative and vice versa.

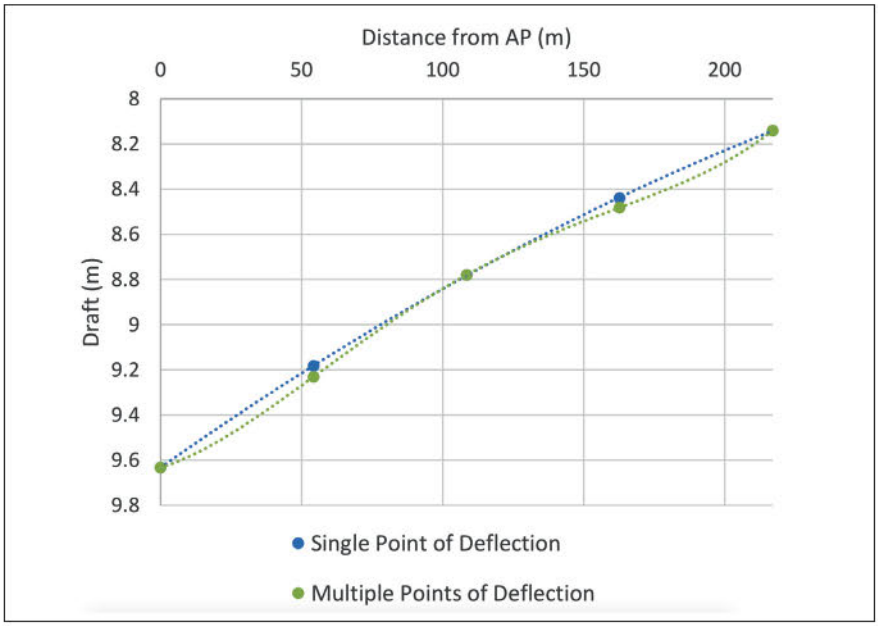
Doing so ensures that the hull shape has Multiple Points of Deflection. In other words, a vessel which was originally hogging or sagging will change to dual sagging or dual hogging, respectively.

Table 2 and Equations 3 and 4 summarise this step. And Figure 4 relates to the use case.

$$(3)\ D_{1/4L} = \left(\frac{DAP+DM}{2}\right) - Def_{1/4L}$$

$$(4)\ D_{3/4L} = \left(\frac{DM+DFP}{2}\right) - Def_{3/4L}$$

Figure 4: Parabolic hull shape of a use case



Step 4: Mean of Means

The final step is calculating the Mean of Means (MoM) and to do so it is suggested using the Simpson's First Rule, applied on Table 2:

$$MoM = \frac{DAP + 4 \times D_{1/4L} + 2 \times DM + 4 \times D_{3/4L} + DFP}{12}$$

Case Study

The proposed algorithm was applied on a use case of a vessel with the following main particulars:

Type – Bulk carrier
LOA – 225.0m
Breadth – 32.26m Summer draft – 14.268m
LBP – 217.0m
Depth – 19.60m
Summer DWT – 74,764tonnes

The vessel arrived at port fully laden and discharged part of the cargo, from holds 2,4,6 only. Initial and final draught surveys were carried out. The initial survey results were plausible when taking into account the reported constant.

Nevertheless, the final draft survey resulted in excessive cargo amounting to about 1.4% of the cargo being discharged. Acceptable cargo quantity deviation is up to 1.0% for smaller vessels, however, for the Panamax bulker it was thought that the deviation was mostly attributable to the parabolic hull shape hypothesis.

Applying the proposed algorithm, the final excess in cargo was about 0.4%, which is considered reasonable by industry standards.

Conclusions

One of the assumptions when carrying out draft surveys is the parabolic shape of the hull. While in many cases this is acceptable, there are vessels in such a condition that they require attention and an alternative solution. This should take into account the vessel's actual shape, which may have Multiple Points of Deflection (MPoD).

An algorithm was proposed and applied to a case study, with results that appear to be closer to reality in the methodology for calculating the Mean of Means of Draft, and consequently the displacement of the vessel, and the cargo being loaded or unloaded, as the case may be.

It is suggested that naval architects, marine engineers and marine surveyors should elaborate upon the proposed method. The author would welcome all comments and feedback. *NA*

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250 years' history of the Spanish Navy Engineers Corps

Jaime Perez Martinez, technical manager at RINA, looks back at the history of Spain's Navy Engineers Corps and the nation's shipbuilding industry over the last quarter millennium

In October this year, the Spanish Navy is celebrating 250 years of the creation of the Navy Engineers Corps. The importance of this anniversary is not only due to the remarkable longevity of a navy corps, but the birth of modern shipbuilding in Spain.

As a country deeply rooted in marine tradition, the Navy and innovation have always gone hand in hand. The development of naval technology allowed the Spanish Empire to dominate the seas and profit from material and cultural wealth for centuries.

From an early stage, the Crown was aware of the need to promote such entrepreneurship, with the most notable examples being the discovery of America and Juan Sebastián de Elcano's first voyage around the world. The latter is celebrating its 500-year anniversary of the 1519-1522 voyage that forever changed global trade.

With Felipe V of Spain (1700-1746) came the Navy's renovation after the damaging War of the Spanish Succession. The ensuing restructuring of the state was heavily inspired by the French and British administrations, with the Navy playing a pivotal role in the securing of territories in Italy and the Americas, among other parts of the Empire.

During the Age of Enlightenment, development of the applied sciences and engineering practices was heavily promoted. The requirements of a modern Navy demanded an industrial focus to its shipyards, which moved from traditional shipbuilding based on craftsmen, to the direct application of scientific knowledge to design and production. This transformation changed from the Spanish system, led by José Antonio de Gaztañeta, to an English system promoted by Jorge Juan, and finally to a French system of naval construction by Gautier.

Jorge Juan y Santacilia's (1713-1773) published works provided vital knowledge for the Spanish Navy's reformation

Jean-François Gautier Oliber, serving under the Spanish Crown, headed the creation of the Cuerpo de Ingenieros de Marina (Navy Engineers Corps). The Navy Engineers Corps was approved by sovereign ordinance on 10 October 1770, 11 years into the reign of King Carlos III. It was conceived as a specialised technical corps, all under the command of an Inspector General of Equipment, who was in charge of supervising the evergrowing expenditure on the required equipment for shipyards.

Nine years later, in 1779, Ferrol saw its first ever three-bridge ship, *Purísima Concepción*, that with a 112-cannon configuration was one of the biggest ships of the line of its time. This was the result of research undergone by Gautier on the plans from the ships of the line *Santísima Trinidad*, the French *Royal Louis* and the British *Royal George*. However, it is worth noting that the 1766-built *San Juan Nepomuceno* was the first to be constructed using the system introduced by Gautier, a ship that would later be the setting for Brigadier Cosme Damián Churruca's heroics during the Battle of Trafalgar in 1805.

The improvements introduced by Gautier were educational, organisational and constructive. His designs aimed to strengthen the resistance of the vessels while increasing their speed and maneuverability. Scantling was also reduced not just for weight concerns, but also driven by material scarcity. During the second half of the 18th

century, the shortage of forest resources in Spain had turned the supply of wood for shipbuilding into a problem that influenced the design of newbuildings and maintenance of the fleet. This allowed for ships that were faster, but more importantly offered improved stability for the artillery.

Around the same time, Jorge Juan y Santacilia published 'Theoretical and Practical Maritime Examination' (1771) and 'The State of Astronomy in Europe' (1774), having previously written the acclaimed 'Navigation Compendium' (1757). Juan's work became vital to the Navy's reform as he introduced technical knowledge from abroad to Spanish ship construction. His achievements also gained recognition outside Spain earning him, among other titles, the Fellowship of the Royal Society for his scientific work in Peru alongside Antonio de Ulloa.

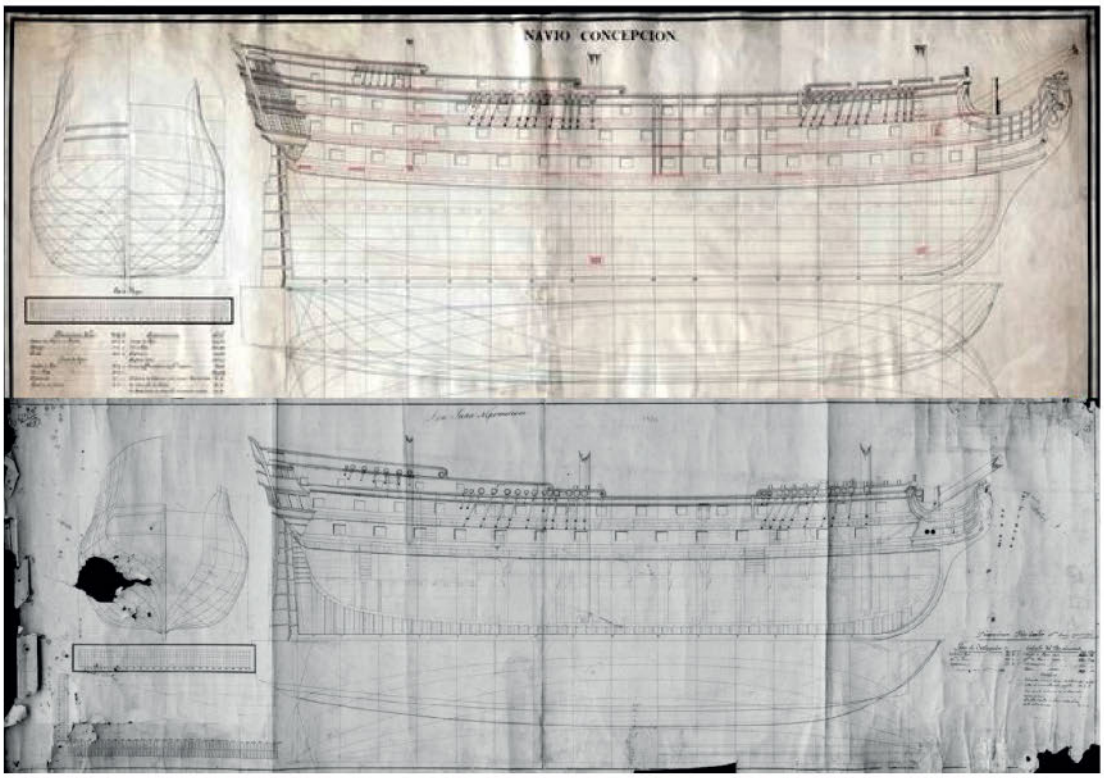
The Navy underwent further reorganisation after the First Carlist War (1833-1840), during which the fleet had been heavily damaged and depleted. This entailed the construction and acquisition of 39 sailing and steam powered ships. The introduction of steam power in the Spanish Navy meant independence from wind and more precise navigation, with paddles quickly being supplanted by screw propellers. Among those purchases, *Blasco de Garay* should be noted, a 350hp steam ship built in 1845 by Money & H. L. Wigram at Blackwall, which is widely considered the first proper warship contracted in Britain.

Political instability during the 19th century proved immensely damaging for the Navy, a situation that was temporarily alleviated with the ascent to the throne of Alfonso XII in 1874. The first Spanish battleship, *Acorazado Pelayo*, was built in 1888 but did not see combat during the Spanish-American War. Coincidentally, that same year saw the launch of the first electric-powered submarine, designed by one of the Navy's greatest innovators: Isaac Peral y Caballero. His design included a system to discharge torpedoes that was tested but ultimately not incorporated into the Spanish naval capabilities.

After 1898, when Spain lost its remaining overseas territories, naval construction contracted greatly, driving officers to work in commercial shipbuilding. The demand for skilled naval engineers increased in this sector that lacked the technical expertise from the Navy, and thus the need for civilians trained in naval construction became increasingly evident.

Yet it was not until July 1917 that the first civilian completed his studies in naval engineering. Thereafter 'officer' students and civilians, known as 'free' students, coexisted until 1927 when the Academy's students were entirely civilian and led to the Navy's decision to close the Academy in 1931. That same year, the Spanish Second Republic government reorganised the armed forces and declared the corps to be disbanded. Other military corps, including the Marine Infantry, were also dissolved. Despite the order being short lived, it created the perfect situation to request that naval engineering education be transferred from the Navy to the education ministry.

The first class saw their studies completed in 1940, for which training was delivered at different locations in Madrid. A permanent site was not established until 1948, taking the name Escuela Especial de Ingenieros Navales, which was later renamed as Escuela Técnica Superior de Ingenieros Navales (ETSIN). This location was the only place where such studies could be undertaken in



Purísima Concepción (top) and *San Juan Nepomuceno* (bottom). Spanish Naval Museum

Madrid's 'Escuela Especial de Ingenieros Navales', currently known as ETSIN

Spain until 1982, when first Ferrol and then other cities introduced engineering disciplines. These studies have remained under the education ministry's control except for the Naval Weapons Engineers School (ETSIAN) founded in 1943. This institution currently provides training for the Spanish Navy Corps of Engineers, and advanced courses. The ETSIAN was the first home of the Naval Weapons Corps, later integrated into the Naval Constructors Corps, with both naval and electrical engineers.

In 1928, coinciding with the order to build the *Canarias* and *Baleares* cruisers (based on the County class cruisers), the El Pardo Model Basin was created. The basin currently operates under the name of El Pardo Hydrodynamic Experiences Center (CEHIPAR) and undertakes experimentation and research into the hydrodynamic aspects of not only military, but merchant, fishing and recreational shipbuilding.

With its creation in 1941, the National Institute of Industry (INI) which sought to advance and promote the development of industry in Spain, became the nation's largest business group. Led by Juan Antonio Suanzes Fernández, a naval engineer from the Navy, it worked to overturn the damaging effects of the Spanish Civil War in the industry. The INI assimilated military shipyards in 1947 when the state took control with the formation of the Bazán National Company for the construction and maintenance of the Spanish fleet. The INI was in turn succeeded by the Sociedad Estatal de Participaciones Industriales (SEPI) in 1995. After numerous mergers between military and civil shipyards throughout Spain, in 2005 the state-owned shipyard Navantia was created, which remains part of SEPI. The company continues to export both civilian and military ships around the world, most notably naval ships for the Norwegian and Australian navies.

The Association of Naval Engineers of Spain (AINE) in Cartagena, the first professional institution, was formed in 1929 when naval engineer Áureo Fernández Ávila realised the need to promote ship design practice. Although civilian by nature, the institution's founding members were from military backgrounds since, among other things, Cartagena is home to Spain's submarine arsenal. With the evergrowing number of naval engineers, the need to create an official body in charge of the profession's organisation became evident and in 1967 the Official Association of Naval Engineers (COIN) was created to protect their interests.

'Modern' naval engineering in Spain has helped its national shipbuilding industry to remain internationally recognised. With gauge rooms becoming increasingly obsolete and the ascendency of computers, Spanish shipbuilding innovation took the lead by creating FORAN, an in-house development by SENER. On the construction side, in 1972 the Astano Shipyard launched the ULCC *Arteaga*, that at 323,000dwt was the biggest ship ever constructed on a slipway. This colossus of the seas would become obsolete once the Oil Crisis ended but its legacy remains a testimony to Spanish ingenuity.

In the years after the Crisis, Spanish naval design experienced a renaissance with technological developments that enabled the Navy to end external acquisition and fully control the design and construction phases. This new generation of vessels included minehunters, corvettes, frigates and submarines.

The story of shipbuilding in Spain is one of sustained effort to innovate and remain relevant in a challenging medium that we are yet to master, and resilience in a constantly changing international landscape. Across the centuries, the Spanish Navy's support of industry's development has resulted in a rich marine heritage, from which present and future engineers and seafarers will continue to benefit. ***NA***

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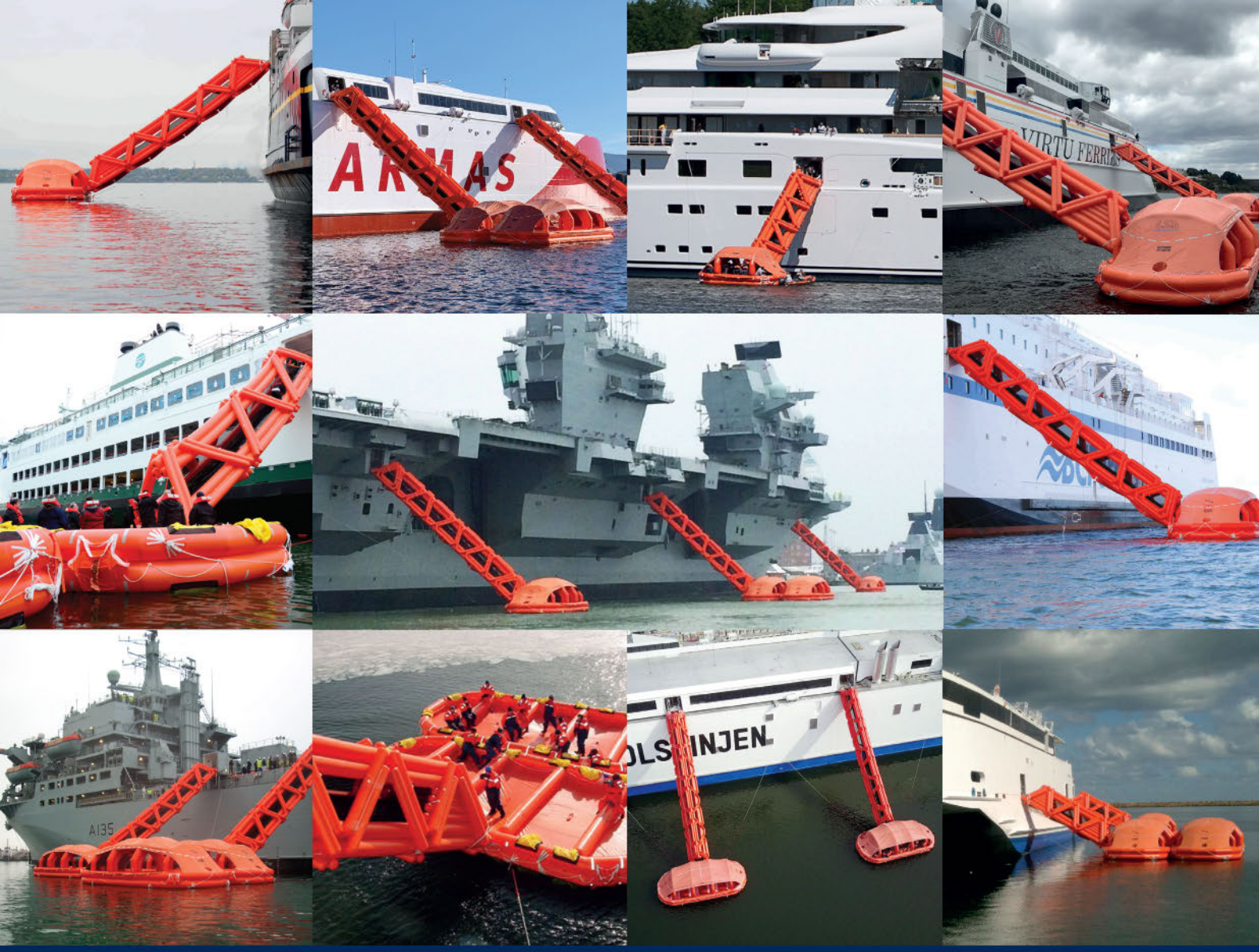

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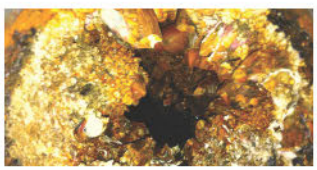


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