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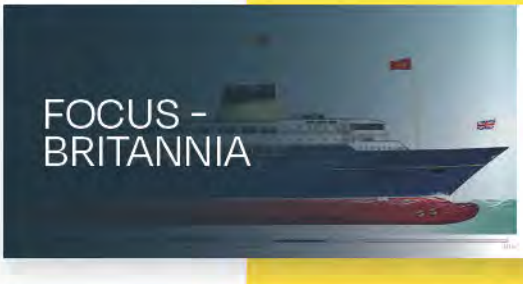

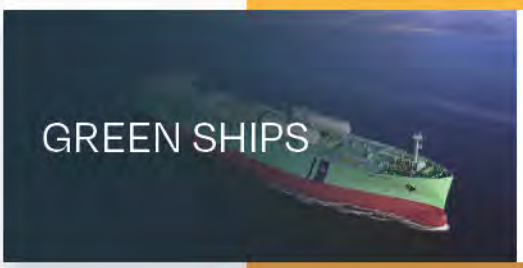

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CARBON INTENSITY FORMULA POSES PROBLEMS FOR CRUISING

By **Richard Halfhide**

MSC WORLD EUROPA WILL INCORPORATE A VARIETY OF GREEN INNOVATIONS. SOURCE: MSC

This month, the 76th meeting of IMO's Marine Environment Protection Committee (MEPC 76) is expected to formally adopt a mandatory Carbon Intensity Indicator (CII) for all ships over 5,000gt as it steps up efforts to reduce shipping's greenhouse gas (GHG) emissions. The CII, which was initially proposed last year, has slipped somewhat under the radar by comparison with the more squarely technological focus of the Energy Efficiency Existing Ship Index (EEXI, see also p28-29), but there are growing concerns in some quarters that it may be another instance whereby the most utilitarian solution may disadvantage certain ship types.

In a recent white paper, Markus Aarnio, chief naval architect at Foreship, suggested that the CII might actually increase the CO_2 emissions of cruise ships. Under CII, ships are assigned a rating from A to E based on their CO_2 emissions and the annual distance travelled. Cruise ships, by their very nature, undertake far less transportation than cargo vessels but this means that they emit a higher relative amount of CO_2. To achieve the best possible CII score, a 100,000gt cruise ship would need to continually travel at its optimum speed of around 12knots, whereas in reality of course a slower speed results in lower CO_2 emissions. If a ship should spend long periods at port, when clearly its emissions will be massively reduced, then counterintuitively its CII rating would similarly drop.

To illustrate, Foreship looked at the four-week itineraries of six 100,000gt vessels with a range of operating profiles, all with an optimum speed of 12knots. It was found that a vessel travelling that averaged the shortest harbour time (10 hours a week in port) and always travelled at optimum speed (158h/week) would achieve a CII score of 9.5, corresponding to a 'B' rating rating. Conversely, a ship that averaged 50h/week in port and 118 hours slow speeding achieved the worst CII score of 16.6, achieving the worst possible rating of 'E'. This is despite having significantly just 1,175tonnes of CO_2, compared to 1,792tonnes for the better rated vessel.

Aarnio comments: "If the proposed CII remains unchanged, life will become very difficult for ships staying in port (without shore power) or at anchor for long periods. This includes residential ships and luxury ships, but also those vessels seeking to reduce fuel consumption by slowing down or staying more at anchor or at private islands. It could also force some ships to increase cruising speed and thus increase emissions."

The paper concludes by suggesting a solution might be to rework the CII so that distance travelled is not part of the formula for cruise ships (unsurprising, given these represent the majority of Foreship's clients). Lest we get too indignant at IMO's apparent shortsightedness, it's worth bearing in mind that although the CII will be used to determine the annual reduction factor needed to ensure the ship's continuous operational improvement, with ships that achieve a low rating for three consecutive years obliged to submit a corrective action plan, there is currently no intention for underperforming ships to be subject to punitive measures. It's also quite possible that amendments to the CII plans will have been proposed at MEPC 76 by the time you read this.

Needless to say this has already been a difficult 15 months for the cruise industry, although there are now the first tentative shoots of recovery. In late May, it was announced that Celebrity Cruises' *Celebrity Edge* would be the first major cruise ship to set sail from the US in more than a year.

Meanwhile, MSC recently resumed operations with a number of short 'staycation' cruises around the British Isles. The company also recently unveiled further details about its forthcoming largest ever cruise ship, *MSC World Europa*, which in addition to being MSC's LNG-powered cruise ship will also feature a distinctive Y-shape design and solid oxide fuel cell system. Quite whether we will have returned normality by the time French shipyard Chantiers de l'Atlantique delivers the vessel next year is anyone's guess. ■

NEWS

EMISSIONS

THE RIPPLE EFFECT OF SHELL'S EMISSION REDUCTION MANDATE

SOURCE: MARC RENTSCHLER

A decision made by a Dutch court will force the influential oil and gas supplier to significantly reduce its CO_2 emissions within the next 10 years.

Climate action group Friends of the Earth Netherlands, as well as the six other bodies and 17,000 co-plaintiffs involved in the original lawsuit filed in 2019, rejoiced this month when The Hague District Court ordered Shell and its suppliers to reduce their CO_2 emissions by 45% by 2030 compared with 2019 levels.

According to Roger Cox, lawyer for Friend of the Earth Netherlands, this decision is significant in more ways than one: "This is a turning point in history. This case is unique because it is the first time a judge has ordered a large polluting corporation to comply with the Paris Climate Agreement. This ruling may also have major consequences for other big polluters."

Responding to the verdict, Shell intends to appeal the decision and highlights the actions and progress it has made in the last five years towards becoming a net-zero energy company. Last year, Shell announced it would meet its net-zero goal by 2050, in line with society's progress towards Paris Agreement goals and inclusive of emissions both from the company itself as well as from customer use of Shell products. And, in September 2020, Shell published 'Decarbonising Shipping: Setting Shell's Course', a document outlining its role in decarbonising shipping and its view on future pathways.

The company stresses: "We are investing billions of dollars in low-carbon energy, including electric vehicle charging, hydrogen, renewables and biofuels. We want to grow demand for these products and scale up our new energy businesses even more quickly ... We will continue to focus on these efforts and fully expect to appeal today's disappointing court decision."

ALTERNATIVE FUELS

A POSITIVE OUTLOOK FOR HYDROGEN DEVELOPMENT IN CHINA

Although China's development of hydrogen is currently focused on onshore infrastructure, there are indications that the country will turn its attention to hydrogen shipping in the near future, according to Yuki Yu, founder of Chinese research and intelligence company Energy Iceberg.

Current priority in China's policy efforts regarding fuel cell is its applications onshore, in areas such as logistics, sea ports and mining sectors, due to a fuel cell vehicle subsidy/funding policy established at national level. "Fuel cell in shipping, however, is not yet the key focus. Nevertheless, as China commits to reach net zero by 2060, many industries are under major pressure to embrace hydrogen as a low carbon transition solution. Therefore, we expect that industry policy makers, in the next five years and toward 2030, will establish more supporting policy and provide some financial incentive for applying fuel cells in shipping," Yu explains.

Application and demonstration of fuel cell shipping research and development (R&D) will firstly take place in China's inland/river systems: the Pearl River, Yangtze River and Grand Canal. A limited number of local projects and demonstrations are already underway in these areas. In Guangdong province, the Green Pearl River initiative will provide local funding to support fuel cell ship applications. Local policies for fuel cell shipping application and R&D have also already been announced by Anhui province, Dalian city of Liaoning, and a few cities in Zhejiang province.

"In these regions, new demonstrations are expected to kick off in the coming years. Despite that the market is at such an early stage, opportunities for shipping industry do exist in our eyes. At this stage, opportunities mainly involve research and R&D cooperations. That means, on a government level, cooperation to develop fuel cell shipping criteria, safety regulations and standards. On an industry level, the opportunities will be surrounding the industry bottlenecks hindering the application fuel cells in shipping."

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DECARBONISATION

IMO'S LIM DOORSTEPPED IN CLIMATE CHANGE FILM

An international team of journalists delivered a stinging attack on the maritime industry's efforts to combat global warming in a new documentary film released online in April.

The documentary, Black Trail, speaks with a variety of shipowners, maritime regulators and environmentalists, in addressing the question of whether the industry is serious in its climate change policy. The film raises some familiar topics, such as the global sulphur cap and the safety of scrubber washwater, while also highlighting the sector's well-established practices of tax avoidance.

Among the commentators are Dynacom Tankers owner George Prokopiu, who speaks in support of IMO adopting instruments backing slow steaming. However, Bryan Comer, director of the International Council of Clean Transport (ICCT) (see *TNA*'s *Green Shipping* supplement, January 2021) counters this by pointing out that cost-saving speed reductions that came into effect during the 2008 financial crisis are still in place today.

The film's most uncomfortable moment comes when IMO secretary general Kitack Lim is doorstepped by one of the film's reporters at his London home, after repeated attempts to interview him. Lim insists progress is being made by shipping on the climate change targets, but adds "I cannot disclose all that is in my heart".

However, industry opinion on the documentary is likely to be divided as to whether it represents a meaningful contribution to the debate or the criticisms of the 'woke' generation.

KITACK LIM, SOURCE: IMO

Black Trail was produced by journalists at The Black Sea and Expresso, Reporters United (Greece), RTS (Switzerland) and VG (Norway), co-produced by SIC TV (Portugal), with research support from Financed Uncovered (UK). The hour-long film can be viewed at: https://theblacksea.eu/black-trail-project/black-trail-documentary-film/

SALVAGE OPERATIONS

SALVAGE STATISTICS REVEAL DRAMATIC DECLINE IN REVENUE

Members of the International Salvage Union (ISU) suffered a 38% decline in income during 2020 compared to the previous year, according to ISU statistics published at the start of June.

The ISU figures revealed that gross revenue had fallen US$301 million, against US$482 million in 2019. In total 182 salvage services were provided, a drop from 216 services the year before.

Although there were 40 cases of Lloyd's Open Form (LOF) salvage agreements, a moderate increase on the year before accounting for US$60 million of revenue, the average value of such cases is US$1.5 million, representing 9% of the average LOF salved value of the ship and its cargo. Salvor revenue from non-LOF contracts, which dropped to US$119 million from US$131 million, is down to US$838,000.

ISU President, Richard Janssen, attributes the statistics to the natural ebbs and flows of the industry: "The economic pressures on our industry continue and we know that on an annual basis activity and income for our industry is variable. The general trend towards a smaller number of larger and more complex cases enhances that annual variability."

"There has also been some structural change in the industry in the last 18 months with the loss of a major player [Ardent, which wound down its salvage activities last year]. That may have had an impact on these statistics but it is not possible to say for certain or to what extent."

Janssen pointed to the recent refloating of *Ever Given*, following its much publicised stranding in the Suez Canal, as demonstrating the vital services ISU members provide to shipowners and insurers.

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NEWS ANALYSIS

WEIGHING UP THE OPTIONS

By **Malcolm Latarche**, Correspondent

With the impending MEPC 76 meeting in June, many of the headlines over the last month appear to be concentrated on the topic of decarbonisation, alternative fuels and related matters.

In mid-May, the Paris-based International Energy Agency (IEA) published its 'Net Zero by 2050: A Roadmap for the Global Energy Sector' report and caused something of a stir. The report is a look at all global energy use and not confined to shipping. Its finding that no new fossil fuels should be used and all funding for new oil, gas and coal supply projects must stop today if the world is to reach net zero emissions by mid-century caused consternation on land and at sea with many politicians and analysts beginning to question the whole decarbonisation narrative.

The report did recognise that shipping along with aviation, steel and cement manufacture, and heavy duty road vehicles would be the hardest sectors of all to decarbonise. It also said that shipping was responsible for 830 million tonnes of CO_2 emissions globally last year, down from 880 million tonnes in 2019. The IEA is forecasting emissions from shipping will decline by 6% annually to 120m tonnes of CO_2 in 2050.

That there are obstacles to decarbonisation in shipping is recognised by pragmatists, with many industry experts saying that the enthusiasm for new fuels and technologies is laudable but confidence in immediate solutions is probably misplaced. Nevertheless, there are some willing to go well beyond the reasonably well supported idea of an International Maritime Research and Development Board (IMRB) and a levy of US$2 per tonne on marine fuels. That proposal would raise US$5 billion over 10 years to be spent on R&D projects.

To be debated at MEPC 76 is a far more drastic proposal submitted jointly by the Marshall Islands and Solomon Islands of a US$100 per tonne carbon price to be imposed on shipping. That proposal was first publicised in March this year but was trumped at the beginning of June when Maersk CEO Søren Skou upped the ante to US$150 per tonne CO_2 equivalent. Skou said that such a levy would help bridge the price gap between fossil fuels and greener alternatives that are currently much more expensive.

Even if they genuinely have enthusiasm for decarbonisation of shipping it is doubtful that many shipping leaders would welcome either initiative gaining recognition as they would add between US$350 to US$500 to the cost of a single tonne of bunker fuel.

SOURCE IEA

For owners that are not in shipping's first division that prospect must be even more alarming since for most of the time they are operating at the margins of profitability.

It was only around six months ago that Skou had made clear that even LNG had no place in the Maersk vision for the future when he said Maersk would: "rather go from what we do today straight to a CO_2 neutral type of fuel, although I suspect that will be years out in the future".

Another container line head, MSC CEO Søren Toft, was signatory to an open letter to IMO member states penned by the World Shipping Council. The letter called for support for the IMRB and made the point that: "If carbon pricing is to deliver results, there must be zero-carbon options".

Toft said later in an MSC statement: "Despite huge investments into the MSC fleet, scalable long-term solutions simply do not currently exist for us to deploy on our ships. There is a gap in R&D to bring these alternative fuels and technologies to the market." He added that improving energy efficiency, LNG and biofuels are currently the only options available.

Both LNG and biofuels have made headlines of their own with DNV's Vessel Insight platform currently showing 20% of all new contracts are for vessels with dual-fuel engines and new fuel ready. Of course that does mean that 80% are still conventional oil-fuelled ships and it is interesting to see that an increasing number of new vessels are specified with both dual-fuel engines and exhaust gas cleaning systems.

Maybe that is not so surprising since scrubber makers such as Wärtsilä, Alfa Laval and Norwegian newcomer TECO 2030 are all talking about the buoyant future for high-tech systems that remove SOx, NOx, CO_2 and particulate matter. ■

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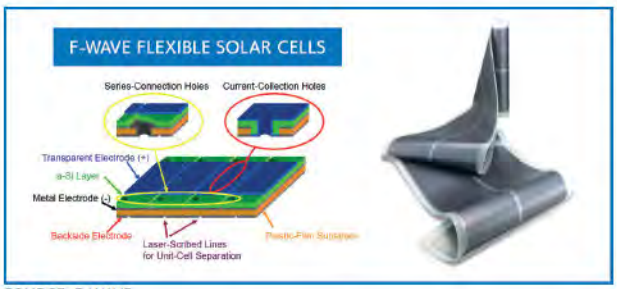
ALTERNATIVE FUELS

SOLAR POWER BACK ON THE RADAR?



SOURCE: F-WAVE

A renewable power source often overshadowed in shipping by other alternative fuels, solar power's outlook could be looking positive with a development project in the pipelines from Japan.

It was recently announced that Eco Marine Power (EMP), a Japanese renewable energy firm, will be partnering with F-WAVE to develop Ship Integrated Photovoltaic (SIPV) solutions for shipping.

Photovoltaic systems, or solar panels, convert light into electricity via semi-conducting materials, and F-WAVE will contribute its patented photovoltaic technology into the partnership. The company's solar cell technology uses a unique structure known as Series-Connection through Apertures formed on Film (SCAF), which allows wireless connection with electrodes. Compared to crystalline cells – silicone cells typically used in solar panels – F-WAVE's SCAF cells' efficiency increases in hot weather conditions.

A specialised version of F-WAVE's photovoltaic technology will be fitted to EMP's patented EnergySail, a rigid sail and wind assisted propulsion device that can be fitted with a range of renewable energy technologies such as PV modules. This fitting will be evaluated at the Onomichi Marine Technology Test Centre (MTTC) in Hiroshima Prefecture as part of the partnership.

EMP are otherwise heavily involved in renewable energy solutions featuring solar power. The company's Aquarius Marine Renewable Energy (Aquarius MRE) with EnergySail, a renewable energy system developed for ships, recently received Approval in Principle (AiP) from classification society ClassNK.

The ClassNK AiP is certified for both the Aquarius MRE and EnergySail integrated together in a solution that combines solar and wind power technology including a system of multiple rigid sails, solar panels, energy storage modules, charging system and more.

BALLAST WATER TREATMENT

PUREBALLAST 3 GETS WEATHER DECK APPROVAL

Alfa Laval has been awarded a Type Approval Design Certificate by DNV for PureBallast 3 Ex, a containerised version of its PureBallast ballast water treatment system (BWTS) that's pre-approved for installation in a deck-mounted enclosure.

Locating the BWTS on the deck is already a common occurrence onboard modern tankers, where there is frequently neither a pump room nor suitable internal space for for a retrofitted installation. What's less well known is that in addition to receiving type approval for the BWTS itself, the enclosure and installation must also be certificated by a classification society. The PureBallast 3 Ex negates this problem, offering a simpler solution for system integrators.

As well as the deckhouse enclosure, the approved design includes the system's internal installation on fixed rails, with all of the internal piping and electrical connections. Although designed to standard container dimensions Alfa Laval says it is built to far more robust specifications, factoring in wind and wave loads, to ensure that the system continues to perform throughout the vessel's lifetime.

"Alfa Laval quickly recognised the importance of having a standardised and purpose-built solution for installing PureBallast 3 Ex on deck," says Peter Sahlén, head of PureBallast. "Likewise, DNV recognised that this would require a unique approach to the approval – given that the solution falls outside traditional class definitions. Working together, we've achieved a design approval that encompasses the reinforcements, insulation, ventilation and other elements that protect ballast water treatment system performance and lifetime."

SOURCE: ALFA LAVAL

CRYOGENIC STORAGE

SAGA PURE BUYS INTO HYDROGEN CONTAINMENT TECH

Norwegian shipowner Saga Pure (formerly Saga Tankers) has acquired a 33% stake in liquid hydrogen storage company IC Technologies (ICT), which recently received class approval for a new onboard storage system for liquid hydrogen or LNG.

ICT's system consists of two stainless steel membranes and two vacuum insulation layers. The primary layer utilises a patented membrane technology which cools the cargo with helium circulation, while the vacuum insulation of the tank prevents heat loss, enables detection and handling of hydrogen leakage from the tank, as well as any leakage into the secondary insulation space.

Classification society DNV recently issued Approval in Principle (AiP) to the new system for liquid hydrogen membrane containment, a significant development for the technology. DNV evaluated the system arrangement, safety systems, and structural function of the insulation panels and the membranes for compliance with IMO's Interim Recommendation for Carriage of Liquefied Hydrogen in Bulk, as well as the IGC Code, and the DNV Rules for the Classification of Ships Pt.5 Ch.7. Because there are still no implemented IMO regulations membrane systems will require the individual acceptance of flag state administrations.

ENGINES

WINGD FLAUNTS ITS FUTURE FUEL ENGINE TOOLBOX

WinGD has published the whitepaper 'Future Fuels: Extending the engine research toolbox to validate clean shipping fuels', which summarises its investments into next-generation fuel solutions.

The Swiss-based engine designer, a wholly owned subsidiary of China State Shipbuilding Corp, has spent heavily on developing sophisticated test rigs to assess the compatibility of any alternative liquid fuel with its existing fuel systems. The rigs typically contain all key elements of the injection systems, for all relevant conditions, including a variety of fuel pumps common rail and injection actuation elements and the injection valves.

WinGD has also vested in a single-cylinder test engine that allows optimisation of both the dual-fuel Otto and Diesel engine concepts. The company explains that this set-up represents a more flexible and cost-effective alternative to multi-cylinder test engines, saving resources during early-stage testing. But at the same time it is also increasing the number of testbeds to improve its capabilities for latter-stage testing.

OPINION

GENDER DIVERSITY IS A PROBLEM FOR EVERYONE

By **Catherine Ingram**, BMT

It may not be immediately apparent, but a lack of gender diversity (and diversity more broadly) and inclusivity in our industry has a negative impact on all of us, as individuals, as organisations and throughout society more generally. This applies to most engineering domains as well as other industries, not just naval architecture. Here are three examples to illustrate this:

1. As an industry, we struggle to recruit and retain enough engineers, regardless of whether they are male or female. We cannot afford to exclude up to 50% of our potential workforce, or fail to recruit the high calibre individuals that we need. In order to ensure that we are attracting the best talent to our profession and its related organisations, we need to make sure that we appeal to individuals regardless of their gender.
2. Diversity of people results in diversity of thought and approach. This allows our teams to tackle problems in a broader way, to consider alternative options and ultimately improve the quality of our outputs and offer better solutions to the challenges we face.
3. An inclusive working environment allows individuals to deliver their best; if you don't feel like you belong in a team or the working environment, this can dent your confidence and consequently prevent you from performing at your highest. This impacts both the individual and the team, so it is in everyone's best interests to make sure that others are comfortable in their working environment.

As engineers we are aware that our industry seeks to solve some of the most pressing problems facing society. We need to develop innovative solutions to these challenges and, to achieve this, we need to be utilising all our resources in the most effective and efficient ways.

It's perhaps easy to think that a lack of gender diversity in engineering is a problem that women need to solve. However, this is an area where everyone can make a difference, and small, simple actions can make a large difference. A few actions to consider:

- Talk positively about engineering as creative and an inclusive environment with your family and friends, particularly young people who might be considering engineering as a career. I was told as a teenager that engineering was a tough choice for a girl; hopefully comments like that will soon be part of the past. The requirements for entry into an engineering career should not be gender-dependent and we should not be giving the impression that it is more difficult for young women to pursue an engineering career than it is for young men.
- Get involved in STEM programmes. These activities help young people learn what engineering is all about, find out if they enjoy and have a talent for the subject and gives us the opportunity to talk positively about our profession (see above). If young people participate in a broad range of STEM activities they can see the diversity of opportunity within engineering. These activities can demonstrate that engineering is a creative subject, focused on problem solving and innovation to counter any impressions of engineering as a dirty, physical profession, which may be less attractive to young women.
- Understand that everyone's experience is different, and can change with time. A few years ago I was the only woman in a large naval architecture department and I found that very isolating. Other women may not have felt that way, but I did. So, don't assume that a given group of people all think, react and feel the same in a given situation or need/want the same support. If in doubt, ask!
- Support the people you work with, regardless of gender. Understand that individuals need training, mentoring, coaching and support. If an individual is feeling excluded from a workplace then offering mentoring and support may help to bring them into the fold and, ultimately, allow them to perform to the best of their ability and to progress in their career.

CATHERINE INGRAM

- Both formal and informal support networks can help give a sense of belonging for individuals who may otherwise feel they are a minority, so encourage formation and participation in these groups, including considering joining networks yourself.
  i. Formal networks: these allow individuals, regardless of gender, to support an organisation's diversity and inclusion efforts. This could include organising events, ensuring PPE works for people with different body shapes, reviewing recruitment material or challenging policies. For me personally, being a part of this more formal network has given me a space at work where I know with absolute certainty that I "belong".
  ii. Informal networks: make a point of introducing women you work with to other females in the profession, and encourage the development of these informal relationships. In a male dominated environment, it can be really helpful to have both female role models and other women to talk to. It is a positive experience to be able to see other people who "look like you" demonstrating that it is possible to have the career that you want. There are also times where, regardless of how supportive male colleagues are, it is just easier to talk to another woman. When society is telling me that I am weaker than my male colleagues it can be very hard to then approach a man and "admit weakness" (e.g. struggling with stress or requiring additional support), even when you know it wouldn't be perceived as such.
- Challenge inappropriate behaviour and watch your own words and attitude. This helps to highlight and, hopefully, correct behaviours when necessary, but it also demonstrates a public show of support for diversity and inclusion. We all make mistakes and sometimes say or do things we then regret (I know I do!). When this happens, acknowledge and correct your own behaviour to set an example for others.
- Ask about people's experience, so you can better understand the challenges faced by those you work with. How you do this will depend on your relationship with individuals; you could, for example, highlight Women in Engineering Day on 23rd June, or send someone a copy of this article and ask them what they think. Remember to respect that some people might not want to talk about this – and that's OK.

About the author

Catherine Ingram, MSc MEng MRINA is Principal Naval Architect at BMT. In 2018, she helped establish BMT's Technical Women Forum to further equality, diversity and inclusion within BMT and the broader industry. In April 2021, she received RINA's Eily Keary Award in recognition of the Technical Women's Forum's achievements.

PASSENGER SHIPS

BRITANNIA REIMAGINED

By **Stephen Payne**, RINA President, 2007-2010

ROYAL YACHT *BRITANNIA*, PICTURED IN 2012. SOURCE: MOSSY CAREY (CREATIVE COMMONS)

The July/August 1996 edition of *The Naval Architect* published '*Britannia* Revisited' – my appraisal of the career of HMY *Britannia*. The last line of the article read: "Discard the concept of *Britannia* and this nation will lose one of its greatest assets and retreat further into mediocrity". Pathetic and prophetic words, for in the event, *Britannia* was not replaced, and the UK lost a highly effective ambassador for trade promotion and State diplomacy.

Royal Yacht *Britannia* entered service in 1954, primarily as a vessel to convey the Sovereign and the Royal Family around the UK and on international voyages of State. The yacht was eminently successful in this role and also offered the setting for royal annual holidays in the Scottish Highlands and outings such as Cowes Week. In 1968, on a Royal Tour of Brazil, the role of *Britannia* was extended to include the promotion of British trade when business executives used some of the State public areas for meetings and conferences in conjunction with the publicity of royal visits. Although not specifically designed for the role, *Britannia* excelled in promoting business, invariably due to the cachet of holding the meetings on the royal yacht with the State Drawing Room, Ante Room and Dining Room being used when the royals were not onboard. However, arrangements were limited by overnight accommodation not being offered. In the final years of *Britannia*'s service, trade deals worth tens and even hundreds of millions were concluded each day she was used in her promotional capacity. To be fair, *Britannia* did spend many idle months each year at Portsmouth between royal engagements,

In the early 1990s with *Britannia* approaching her fifth decade of service, HM Government considered a replacement vessel and endorsed a cut back yacht with

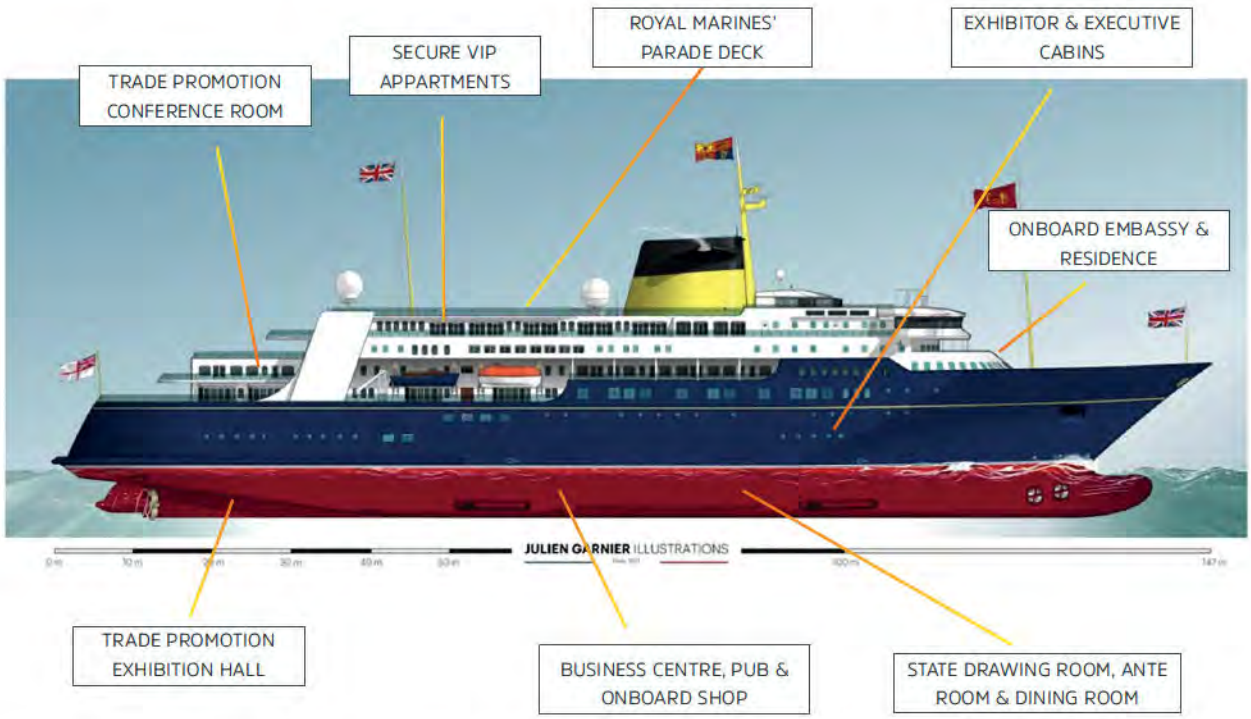
fewer facilities and operational capability. This was quietly dropped when it was realised that it simply wouldn't have been able to adequately fulfil the various required roles and duties. *Britannia* sailed on and in 1995, it was announced that she would be withdrawn in 1997 and a review would be made to consider whether a replacement would be built. The Government prevaricated until early 1997, when just before a General Election, it was announced that a new yacht would be built. This decision was subsequently reversed by the incoming administration in October 1997, whilst *Britannia* decommissioned that December to become one of Scotland's most popular tourist attractions based at Leith, Edinburgh.

Fast forward 24 years. Brexit. Coronavirus. Business stagnation and high unemployment. All a toxic mix that could in part be alleviated through building a new kind of royal yacht, one dedicated to promoting British interests in a much more intensified capacity than *Britannia* ever could or did. I've chosen the phrase "British interests" carefully because I believe that a new yacht should expand her portfolio of activity beyond promoting international trade and services to everything the UK has to offer – culture, heritage, tourism, youth, and more. It is worth noting that previously I mentioned that *Britannia*'s success was largely due to her being "the Royal Yacht". Ceremonial and State visits, State dinners and receptions and the Band of the Royal Marines all worked to provide the allure and imbue *Britannia* with the required cachet – and this must be replicated on any new yacht. But these attributes need to be expanded to include all the facilities required to rigorously promote business and trade; a conference auditorium with break-out room, an exhibition hall, dedicated meeting rooms and a business centre. After all, why would business meetings and conferences be held onboard the confines of a yacht when better facilities could be found on shore? Certainly, the lessons of the failed 1990's replacement project must be remembered.

On 29 May this year, HM Government announced that a new "National Flagship" was planned at an estimated cost of £200 million and an illustration of a two-masted vessel was released depicting how the ship might look. Although details were scant, it was announced that the ship would be crewed by the Royal Navy and would be in service by 2026. With only two masts, this vessel can't be classed as a "Royal Yacht" in the traditional sense as three masts are required. If the illustration is accurate, it's also unlikely that it would be of sufficient size to simultaneously host conferences, exhibitions and receptions of any significant size.

Notwithstanding international capabilities on designing and building large yacht-like vessels, as befits the UK 'National Flagship', the design of this ship from concept design through to detailed design should showcase British capabilities. This was clearly endorsed by Prime Minister Boris Johnson who stated: "Every aspect of the ship, from its build to the businesses it showcases onboard, will represent and promote the best of British – a clear and powerful symbol of our commitment to be an active player on the world stage." Building such a vessel in itself would be welcome work for any UK shipyard. Cammell Laird cut its teeth on the recent *Sir David Attenborough*, but what better shipyard group to launch this ship than Harland & Wolff, brought out of administration and revitalised by Infrastrata? In conjunction with British design and as much British equipment and innovation as possible, the yacht would be an international showcase for all things British Maritime.

In the last years of her commission, *Britannia* was costing around £12 million per annum to operate, refits excepted.



HER MAJESTY'S TRADE & BRITISH PROMOTION YACHT *BRITANNIA 2*

BRITANNIA 2. CONCEPT PAINTING COURTESY PATRICK JACKSON

Surprisingly, the running costs of *Britannia* were met entirely by the Royal Navy/Ministry of Defence, and the Home and Foreign Offices, whilst businesses using the yacht did so complimentarily. It is clear, in 2021, any new yacht project must be as far as practicable self-financing to not unduly rely on the public purse and the Exchequer. Indeed, squeezes on the foreign aid budget and the extent of funds to be made available for child catch-up education due to Covid-19 has already led to allegations that, "money can be found for a Royal Yacht but not for the people's priorities." Any cruise line executive worth his salt will tell you that economy of scale is the key at maximising revenues against costs; is this axiom reflected by the Government's proposed vessel? With a build cost of £200 million (effectively £42,644 per day, every day for 15 years at 2% interest), plus considerable annual running costs, the vessel will be required to generate considerable revenues from her facilities. Clearly, the Government must release details of how their project will generate sufficient revenues to cover these costs.

Crewing will be a major issue. A Royal Navy crew is a laudable ambition but will be very problematic. The Royal Navy struggles to recruit sufficient sailors to keep even the existing fleet at sea and some ships are now semi-permanently docked with a reduced compliment. As the Fleet is due to expand, the situation can only become more acute. A prestigious vessel such as the UK national flagship will need a disproportionate sized crew of chefs, laundry staff, etc to maintain standards, all the very class of sailors that reportedly the Royal Navy struggles to recruit. How long after all the pomp and circumstance of building and naming has subsided, will the new ship be viewed as an operational burden? A new approach is surely needed, possibly with a mixed Royal Navy and Merchant Navy crew. What about dual RN and MN flag – a real first as befits the nation's flagship? The hotel side of the ship could even be run as an elite training college with experienced staff mentoring enthusiastic juniors in hotel and catering, much like Jamie Oliver's Fifteen concept.

The author believes we need a true national flagship. A ship able to pay its way with full-scale exhibitions and conferences as found ashore, an onboard Embassy with a diplomatic mission, a trade suite and meeting place for businesses large and small, elite sports people and youth – promoting trade, tourism and culture and still have the space for the signature State and Royal Apartments that would give the ship its true status. We are a maritime nation and the leaders and innovators who have defined our nation in the past wouldn't expect anything less.

My self-financing proposal for a national flagship would embrace the following key points:

- Continuous 'Festival of Britain' worldwide trade promotional role with dual-purpose exhibition hall and separate conference room, private business break-out rooms, business centre, British pub and restaurants for exhibitor/executive dining, *Britannia 2* shop (ship logo, Royal Collection and British trade/commerce items) and a small museum
- Ambassadorial role with VIP Apartments of State including Drawing Room, Ante Room and Dining Room as former HMY *Britannia* for State receptions and entertaining in UK waters and worldwide
- Projected operational profile with revenues and expenses based on a full around-the-world itinerary based on 328-day voyage comprising 51 ports with 157 conference days and 103 exhibition days
- Cost neutral – Build and operational costs met through onboard operations of conference centre, exhibition space, business centre/meeting rooms, hospitality restaurants, and VIP/executive cabins
- Storage onboard for quayside 'pop-up' marquee with electrical and air-conditioning connection to the ship's services for extension of exhibition and reception capabilities
- Separate cabin accommodation with applicable security for VIP and trade promotion executives
- Latest eco-friendly 'green ship' technology including hybrid propulsion with British equipment and technology as far as practicable
- Imaginative ship manning proposal predominantly through former military service personnel wishing to remain at sea post-Royal Navy or other service and Merchant Navy officers and crew
- Cadet and apprentice contingent for onboard training
- Hotel services (including exhibition/business meeting services, catering, cleaning, laundry), apart from VIP accommodation, to be provided by onboard hotel and catering college in collaboration with existing British catering and hospitality organisations and chefs
- Proposal for first ever 'dual-flag' Royal Navy and Merchant Navy vessel with Royal Navy master
- Permanent onboard Ambassador with floating British Embassy status
- Showcase for British Industry, shipbuilding and culture
- Design and construction to be overseen by the team that delivered *Queen Mary 2*

About the author

Stephen Payne is a former President of RINA and is the Designer of Cunard Line *Queen Mary 2*, a Royal Designer for Industry and a finalist of Prince Philip's Designers Prize 2006. He was awarded the Royal Academy of Engineering Special Achievement Award 2006. ■

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CONTAINER SHIPS

RINA WORKSHOP TACKLES CONTAINER SHIP SAFETY

By **Richard Halfhide**

IMAGE: RINSON CHORY

Remarkably, it's less than 12 years since the *CMA CGM Marco Polo* set a new benchmark for container ships with a capacity of 16,020TEU, a figure that already seems modest compared to the current record holder, 23,964TEU *HMM Algeciras*, launched last year. But with that supersizing have emerged manifold safety concerns, particularly with regard to the disturbing frequency of container ship fires (see *TNA*, March 2021) the loss of containers overboard (*TNA*, Jul/Aug 2020) and more recently *ONE Apus* (14,000TEU), which lost 1,800 containers in heavy weather. In an effort to explore how these problems might be addressed, RINA's Safety Committee held a special online workshop in May where members were invited to share their opinions and insight.

By no means are these problems reserved to the very largest ships. So exponential has been the economy of scale in the segment that in recent years fleet capacity has regularly exceeded demand. While very large container ships have come to dominate the Asia-Europe and transpacific routes, ships that have found themselves surplus to requirements have cascaded down into service on shorter haul journeys.

Notwithstanding the question of whether upscaling necessarily represents an optimal solution, it generates a host of technical issues that naval architects are perhaps the best qualified to advise upon. In his keynote address, David Tozer, former global head of container shipping at Lloyd's Register, commented: "It's our responsibility to ensure that technical challenges are dealt with to the best of our ability by promoting appropriate research, suitable analysis tools and education to ensure that those who own, plan, insure and sail these vessels are aware of matters which must be considered when sending them to sea."

Multifaceted problem

Container ship stability can be generally said to begin with the matter of the container stacks themselves, and ensuring that the cargo can be safely loaded, lashed, transported and unloaded with minimal complications. Most incidents involve some kind of stack failure but Tozer noted that very often the precise causes are unclear. There may be issues with the containers themselves, their lashing, overloading of the boxes, poor weight distribution, or flaws in the motion prediction or lashings calculations.

The phenomena of parametric and synchronous rolling are frequently cited in incidents of container losses and Tozer questioned whether currently there are satisfactory models to calculate the six degrees of motion that these ships experience at sea. "We have the lashing calculation methodology itself and at three to five tiers high linear

methods work very effectively. But now we're running to much higher tiers, the mathematics is horrendous."

He added: "To try and put more complex research analysis methods into the loading computer is almost unworkable, because the ship will have sailed by the time the computer's finished checking the entire stow. We've yet to find that intermediate solution where you perhaps lose a tonne or two of cargo capacity but have got something that actually works in the real world."

John Dickinson, a master mariner and harbour master who spent several years planning container ships for ACT and Blue Star Line, thinks one of the main problems with containers is the loading of the individual containers. He commented: "Even if you've got quite a light container eight containers up, if the cargo inside starts moving with the ship moving it compounds it and that's when you start losing containers. It's difficult to know how a container is packed, you're at the mercy of freight forwarders and the people who stuff the containers."

Lashing solutions

Paul Coley, former marine surveyor and assistant director with the Maritime Coastguard Agency (MCA), involved with ship surveys and developing regulations and guidance, warned that there may be a limit to what naval architects can do in such matters, which often have more to do with operation than design. Rather, he thinks they could focus their efforts on the design of lashing and containers. "When the topic was raised at one of the P&I club forums, the subject was put forward that perhaps it's time to have the container guides running the full height of the stack, so that there was less involvement, from an operation aspect, to put tie bars on lashings to secure the cargo," he observed.

Dickinson recalled that in earlier times it had been the practice to secure the top tier on deck with what were known as bridging pieces, whereby side-by-side containers were adjoined by the corner fittings. One retired member who had been involved in developing the original rules for container securing arrangements observed they had been conceived at a time when container stacks were a mere three high and capacity typically around 1,000TEU.

One of the problems, according to Tozer, is that many ship operators are continuing to refer to standard cases in the Cargo Securing Manual (CSM) which don't factor in the forces at work on a larger ship. That said, it is highly unusual for larger ships to reach anywhere near the limit for 14tonnes containers that are normally specified for Panamax vessels, with the average weight of container being three or four tonnes.

Many people don't appreciate that the container stacks are very often standing in total isolation from neighbouring stacks. While a variety of manual and semi-automatic twistlocks are deployed for container lashing, safety rules mean that the days when stevedores would climb up to great heights to secure them are long gone. This means that anything out of reach depends on automatic twistlocks, but the combined rolling and heaving motions of a ship can lead to situations where these don't lock and in some cases can unlock whilst underway in heavy weather depending on the ships motion.

Tozer explained: "If you see a stack of containers where the whole stack has fallen over you can be pretty sure it's been secured with semi automatic twistlocks. If you find the containers have come apart or they're standing on their ends that could well be they're using fully automatics.

Regarding the Cargo Securing Manual (CSM), to approve a CSM on form and content is one step, but quite often the technical content of the CSM is also approved by class. I believe that's also a good option, otherwise who's verifying the stowage arrangements and the standards?"

Stronger, smarter containers

Although the 'Father of Containerisation', Malcolm McLean, had originally envisaged a standard box, the modern reality is somewhat more complex. Nowadays, there are a variety of different container lengths and heights defined by the International Organization for Standardization (ISO), with only the width remaining consistent. Added to that is the question of whether those standards are fit for purpose when it comes to boxes stacked to such great heights. Given the millions of new containers manufactured annually, Tozer suggested it might not actually be such a huge undertaking to implement a new standard, and some shipping lines already have their boxes built to more exacting specifications.

It was questioned whether the Industry was guilty of dumbing down safety standards, citing inadequate fire safety and minimum manning among other factors. It prompted further discussion of the problem of container fires, with Coley mentioning a system developed by operator Evergreen (in the aftermath of *Ever Decent*'s 1999 collision with cruise ship *Norwegian Dream*) which led to the SOLAS requirement for the provision of water mist lances capable of penetrating the container wall, which has been mandatory since 2016.

Coley also suggested that there might be a time in the future when each container might have its own fixed fire extinguishing system installed, perhaps connected to the ship's fire main. The idea was met with general approval, while regular *TNA* contributor Dennis Barber observed that gas inerting technology has long been a mainstay onboard tankers. Nevertheless, the perennial problem remains cargo misdeclaration and the probability that less scrupulous operators who would sooner avoid costs.

The technology to make containers smarter and easier to trace undeniably exists and Sarah Watts, former chair of the Safety Committee and Consultant Naval Architect, proposed amongst other things that containers could be equipped with transponders to make it easier to locate boxes lost overboard. The apparent disregard that operators show towards retrieving lost containers – despite the fact they are now classed as pollution under MARPOL Annex V and may contain hazardous materials – was also a point raised by Coley later on.

Commercial pressures

Indeed, the spectre of commercial pressures was a recurrent visitor during the workshop. In response to the question of who would incur the financial penalty

if a voyage had to be extended due to heavy weather, Dickinson said that the captain wouldn't be deemed liable for taking due care, although missing the berth through lateness might be a matter for litigation in other links in the supply chain. Coley drew attention to research by the MCA, in partnership with shipping companies and P&I clubs, into human behaviour and why people in all facets of the maritime industry are often inclined to take shortcuts and the cumulative effects this has on undermining ship safety. Coley also mentioned that both IMO (MSC Circ. 1228, 2007) and the MCA issued (MIN 357, 2010) have issued applicable guidance to mariners on navigating safely in adverse weather.

Tozer believes the solution is ensuring everyone in the chain of command understands the risks that they're taking. "The guys on the ship know what needs to be done, but is the guy back in the office going to accept their decision to slow down or cost the company some money? So it's getting that relationship right. Training and education."

Dickinson had earlier remarked that while the ISM Code states that the crew of large container ships should be adequately trained in operations of the ships they are serving on, in this case a container ship. The Masters and officers should have an understanding of parametric and synchronous rolling, and appropriate simulator training can be useful in this respect.

Stability and hull structure

The question was raised of whether so-called Second Generation Intact Stability criteria really represents an improvement on current standards, or whether there are other factors that need to be addressed more specific to the characteristics of container ships. Coley observed that the matter has been a topic of debate within IMO for a number of years and may have over complicated the matter; furthermore it will also be necessary to take into account the weather, the direction, speed and other operational aspects.

Another query was whether there is sufficient understanding of the structural dynamics of ultra large container ships when fully laden, or if there might be phenomena that are currently not understood and might lead to changes. Tozer pointed out that a lot of significant research on hull structure, such as the effects of whipping and springing, have been conducted over the past two decades and applicable class rules now exist.

"Torsion is a complex phenomenon because twist applied at one end of the ship, produces stresses at the other end of the ship. You need to consider the distribution of the torque along the ship to get any meaningful answers out, which is not done in the loading computer at the moment, so that's a weakness in terms of the calculated stresses in the hull structure. This is particularly relevant for large ships because their large beam means that a large torque can be generated in the hull."

In addition, significant twisting of the hull can occur during loading and unloading and Dickinson pointed out that while certain stresses can be exceeded while in port a ship must be restored to at-sea limits before sailing. Coley commented that many of these issues were

IMAGE: DAVID TOZER

brought to the fore by the Marine Accident Investigation Branch's report on the structural failure of the *MSC Napoli* in 2007. He added that the thickness of the steel particularly in the sheer strakes might be a potential weakness on the largest ships, where it is difficult to guarantee the uniform quality of high tensile materials in different loading situations and temperatures.

Size the limit?

The growing reliance on container loading software was raised again shortly after. One contributor pointed out that because there is no requirement for the software's lashing module to be approved by class, its calculations may be inaccurate or not fully aligned with the CSM, if indeed a lashing module has been provided at all. They added that: "The latter then means that crew need to resort to manual verification of the lashing forces with reference to the CSM, which may not be practical for a very large ship during a short/busy port call."

Another delegate pondered whether size limits might be suggested to IMO and imposed by SOLAS, but Tozer pointed out that competition between operators to have the largest ship was always likely to undermine attempts at legislative control. However, the dimensional limits of the Suez Canal are now being reached and although draughts are remaining at stable levels, container stacks are increasingly in danger of insufficient clearance space under a number of major bridges around the world. Another potential drawback could be the reach of gantry cranes, which can typically extend to 60m but would likely require the significant reinforcement of numerous quaysides if they were to become any bigger.

It is hoped the workshop will help spur discussions on relevant research topics both within universities and the wider industry to address technical areas where safety might be improved by RINA members' technical expertise. Since the workshop took place the loss of the 2,700TEU feeder ship *X-Press Pearl*, which caught fire and sank off the coast of Sri Lanka in early June, causing hitherto uncertain ecological damage. ■

A full recording of the event is available on RINA"s YouTube channel at: https://www.youtube.com/watch?v=WL0Y2w_csMY. Those wishing to contribute further thoughts or suggestions on this matter should contact: GGigantesco@rina.org.uk

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NORWAY

OCEAN NOW – A NOR-SHIPPING TASTER

By **Sophie Collingwood**

SOURCE: SHUTTERSTOCK

Nor-Shipping 2021 became one of many victims of the Covid-19 pandemic, now delayed until 10-13 January 2022, but its two-day hybrid event Ocean Now – an activity programme of in-person and online talk shows, forums, presentations and more – took place on 1-2 June in Oslo, Norway.

Central to the entire programme was 'taking #ACTION', drawing attention to the people, products and innovative solutions that are instigating progress and results for the maritime industry, with major Norwegian Nor-Shipping partners such as Norwegian bank DMB, marine insurers Skuld and coating specialists Jotun taking centre stage. Unsurprisingly, shipping's long-term emission goals for 2030 and 2050, compounded by IMO's upcoming implementation of EEXI and CII measures, put decarbonisation and its demands on the entire maritime ecosystem at the forefront of discussions.

Inter#ACTION for Norway

After a turbulent last 12 months, the Norwegian Maritime Authority (NMA), Maritime Bergen and WISTA Norway took the opportunity to reflect on the progress the Norwegian International Ship Register (NIS) has made since the 1980s, when its own flagged ships were almost entirely eradicated from the world's oceans. Established in 1987, the flag registry revitalised its industry and recently reached a milestone goal of 700 Norway-flagged vessels.

Norway is already the fourth largest fleet in the world by value, and the NMA's vision is to become the preferred maritime authority. Maintaining the communication loop with customers and possessing an entire toolbox of in-house knowledge sets the authority apart, acting general director of NMA, Lars Alvestad, explains: "With the expertise and competence we can offer through our staff, the NMA is a complete administration with in-house technical expertise, and a lot of other flags do not have that. In an uncertain and often unstable geopolitical world, the Norwegian flag offers significant security advantages and support, for instance through our cooperation with Norwegian foreign affairs."

The Norwegian Shipowners Association has decided on a zero emission target for 2050, and NMA intend to be a player in these ambitious climate goals. "Of course we have a role to play and we shall play it, we see ourselves as a bridge between the IMO and industry and authorities here in Norway. We are doing that by making sure we have the internal expertise needed to develop regulation and influence policies that enable innovation and technical growth."

Challenged on how NMA will play its role in the green revolution of shipping, Alvestad draws attention to the authority's recently established centre for new technology, among other actions: "We have also founded, together with two other flag states and

some classification societies, a technical international forum that will help our customers to gain international acceptance for new technologies."

Challenges of a decarbonised future

Experts from DNV took to the virtual platform to discuss its lessons learnt, progress made and advice going forward for decarbonisation as the Norwegian classification society asked the industry to turn its foresight into action.

DNV stressed the importance for shipowners and managers to prepare a robust ESG and sustainability strategy fit for the future. As Lin Hammer Jacobsen, business development and training manager at DNV, noted: "Green and sustainable financial products are becoming the new ticket to trade and business as usual is not an option anymore. Investors want to see a company strategy with a clear ESG focus, dedicated ESG targets and an implementation plan before they decide if they want to invest in your company."

Increasing pressure on the industry to decarbonise was next on DNV's agenda, acknowledging that the most imminent issue shipowners are requesting support for of late is the energy efficiency existing ship index, EEXI. The class society is confident that compliance measures are within reach for most vessels to meet the one-time event index but warn that IMO's carbon intensity indicator (CII), which will require ships to improve their carbon intensity on a year-on-year basis, could prove more challenging. "Owners need to set targets and start preparing strategies and fleet transition roadmaps for the decade, and sooner rather than later shift to alternative fuels," urged Mathius Sørhaug, business development leader, maritime advisory at DNV.

A move away from fossil fuels is inevitable, but what comes next? DNV's Maritime Forecast to 2050 models show that shipping will need to rely on a much wider variety of alternative fuels, but each one faces barriers in their uptake. Whether that's technical maturity, storage, cost or, in the case of ammonia, fuel availability, infrastructure and safety. DNV highlighted its commitment to overcoming this safety barrier for ammonia uptake. It recently published its '*Ammonia as a Marine Fuel Safety Handbook*', and in July 2021 will publish class rules for ammonia and fuel ready notations preparing ships for conversion to fuels covering ammonia, methanol/ethanol, LPG and LNG.

For a vessel built today, the most competitive fuel for a ship's early life will not necessarily be the same as at the end of its lifetime, and Linda S. Hammer, principal consultant, maritime advisory, DNV, asked the industry to look ahead: "Considering the large uncertainties of the lifetime of your ship, you therefore need to plan for fuel flexibility and fuel ready solutions. By doing so, you stay below the relevant carbon intensity reduction trajectory, thereby minimising the risk of investing in stranded assets."

Fuelling the future with hydrogen

Compressed, liquefied or as a fuel cell, hydrogen dominated day two of the programme. Global representatives from Japan, South Korea, China, Canada, Australia and Norway outlined their national efforts and progress with hydrogen as fuel in shipping. But ambitious targets for hydrogen-fuelled vessels rely on the relevant technology, infrastructure and funding being in place.

CEO Stian Askre of Norwegian hydrogen fuel cell producer TECO 2030 discussed plans to establish the country's first large-scale production of hydrogen-based fuel cells in Northern Norway: "We see that demand is growing and it needs to be filled. Hence our doubled efforts, with the factory starting serial production in a fairly small scale in 2023 and then our current development of a dedicated marine fuel cell." Norwegian ferry company Norled's chief commercial officer, Lars Inge Vågen, commented on the obstacles faced while developing *MF Hydra*, its soon-to-set-sail vessel initially running on battery that will, early next year, become the first hydrogen-powered ferry in the world. "We are walking down a path where no one else has been walking. The regulations are not ready so we need to work on a risk-based approach towards DNV, and it requires a very close collaboration with the whole value chain in order for us to complete this first vessel by early next year."

The proposed carbon levy to accumulate R&D funding was also hot topic during discussions, as a potential method to accelerate uptake and development of hydrogen and its infrastructure. Ro-ro vessels from Topeka will have containerised hydrogen to transport the fuel around the Norwegian coastline. But as Steinar Madsen, Topeka AS CEO pointed out, the challenge comes with transitioning away from pilot scale volumes: "We need to find a way to make a roadmap from the small production size to large size and how to cover the additional cost [...] maybe the levy could also finance a kind of contract of difference to support that cost in this early phase for new fuels."

The Norwegian Hydrogen Forum (NHF), a non-profit association promoting the advantages of hydrogen, has witnessed the development of related technologies in the 25 years since it was founded in 1996. Its chairman, Steffen Møller-Holst, believes Norway is ideally positioned to take advantage of its prospects: "15 years ago, the attention to hydrogen and fuel cell technologies was much higher in Europe than it is in Norway. But we have the pre-requisite, we have the energy sources, we have industry and we also have funding schemes in Norway and not least the very high ambitions for reducing the emissions from maritime transport, cutting back by half by 2030. So I think we might, in Norway, play a pivotal role toward decarbonising shipping as a sector."

Jarand Rystad, CEO of Oslo-headquartered Rystad Energy, stated that the world is waking up after the pandemic in an energy transition. As such, decarbonisation, alternative fuels, regulations and more topics touched upon this June can be expected to be in full force at Nor-Shipping in January next year. ■

BULK CARRIERS

HEADING TOWARDS A BIOFUELLED FUTURE

By **Sophie Collingwood**

Established in 2015, Netherlands-based company GoodFuels have since been championing sustainably sourced biofuels for maritime use. In its latest endeavour to put the alternative fuel on the world map, GoodFuels has completed a joint project with German shipping company Oldendorff, global resources business BHP and the Maritime and Port Authority of Singapore (MPA) for the first marine biofuel trial involving an oceangoing vessel in Singapore.

The maritime industry has very limited incentives to decarbonise, and the current targets set out for decarbonisation are still preliminary and distant, Isabel Welten, chief commercial officer at GoodFuels, tells *The Naval Architect*: "That's why we think that partnerships such as the one between GoodFuels, BHP, Oldendorff and the MPA are very important for the sector, because they show that it is possible to make an impact on those broader societal goals today."

Supported by MPA, the project saw one of Oldendorff's modern Kamsarmaxes, the 81,290dwt, 2020-built dry bulk carrier *Kira Oldendorff*, refuelled in Singapore with a drop-in advanced biofuel blended with conventional fossil fuels. Although in this instance a bulk carrier was chosen for the bunkering trial, Welten highlights the product's versatility: "As biofuel is 'drop in' and can be used in a blend with conventional fossil-based marine fuels, it can work with any vessel type; and these characteristics are becoming increasingly recognised in the maritime industry's owner/operator community." She adds that the company does encourage its customers to use its 100% biofuel product but, despite most customers' preference for pure biofuel, some do ultimately opt for a blend.

GoodFuels' advanced biofuel, as used in the blend onboard *Kira Oldendorff*, is sustainably sourced, verified and approved by an independent sustainability board. Using sustainable waste and residue streams as feedstock for a fuel capable of 80-90% well-to-exhaust CO_2 emissions compared with HFO/VLSFO and which virtually eliminates SOx emissions: "They're produced from certified feedstocks labelled as 100% waste or residue and have no (in)direct land-use issues and no competition with food production or deforestation. We select certified feedstocks, such as used cooking oil, crude tall oil, sewage sludge or tallow," Welten confirms.

For the trial, Oldendorff installed monitoring instruments onboard the bulk carrier to capture trial data from using the drop-in biofuel, which Welten comments requires no changes to a marine engine: "One of the most favourable and commercially attractive elements of our biofuels is their drop-in characteristics, meaning that no technical or hardware changes are required to burn our fuel. Moreover, we can continue to use existing bunker infrastructure. This considerably lowers the barrier to entry to using the fuel on existing and newbuild ships," she explains.

GOODFUELS' BIOFUEL BUNKERING TRIAL ON A BULK CARRIER IN SINGAPORE

Singapore has been in GoodFuels' sights for a while, Welten tells *TNA*, adding that a first trial for bunkering at the hub was planned in 2017/2018 but did not go ahead as the industry and local supply chain was unready at the time. As such, this joint project is particularly significant: "It has taken us substantial effort to enable the bunkering of our marine biofuel to be carried out in Singapore, as all the technical, operational and commercial aspects needed to be right. We're immensely proud to have been part of this incredible milestone for shipping – bringing an immediate decarbonisation solution to shipping's most important global hub – as we believe passionately in the industry's decarbonisation vision."

The joint project aimed to understand the behaviour of the fuel, assess engine and vessel operational performance during the trial, and explore the technical/commercial merits and challenges of biofuels as a marine fuel. While the exact results of the trial are undisclosed, Welten is confident that the project will help inform future decisions on the supply and use of biofuel: "All the learnings and findings from the trial are being used to complete strategic analyses and recommendations on the owner, charterer and GoodFuels' side, at which point the next steps will be clearer. The technical results are also being carefully analysed before further plans commence, which may include more trials."

Although the bulk carrier project is a breakthrough for the company, GoodFuels plans to expand the scope of biofuel beyond any one segment. "For GoodFuels, our mission has always been to accelerate the energy transition by using truly sustainable solutions. We are advancing the use of second-generation, sustainable marine biofuels across all maritime transportation," Welten comments. ■

THE WIND BENEATH BULK CARRIERS

By **Sophie Collingwood**

BARTECH WINDWINGS BY YARA MARINE TECHNOLOGIES (LEFT), ANEMOI MARINE TECHNOLOGIES' ROTOR SAILS (RIGHT)

Wind assisted propulsion (WAP) solutions are becoming increasingly prevalent in the bulk carrier sector, with the likes of Mitsui OSK Lines (MOL) developing a large, 60m high rigid wing sail on a coal carrier scheduled for delivery in 2022 (See *TNA* May, p22). Offering anywhere up to around 30% reduction in fuel consumption, and consequent CO_2 emissions reductions, wind-powered projects that will potentially see installations on entire fleets of bulk carriers are in the works as shipping approaches IMO's 2030 carbon reduction target.

"All forward-thinking vessel owners are now thinking of wind propulsion. It is, however, currently better suited for retrofitting to some of the global fleet more than other vessels," John Cooper, CEO of BAR Technologies, tells *The Naval Architect*. In April 2021, the company announced it was joining forces with Yara Marine for an exclusive partnership that will see the first commercial retrofit of WindWings technology on a Cargill vessel, expected for delivery in 2022. This will be a step forward for WindWings – a wind propulsion device of solid wing sails measuring up to 45m high which are installed on the deck of a vessel to harness wind – the design particulars for which have been kept closely under wraps by BAR Technologies (See *TNA* June 2020, p26).

Henceforth known as BARTech WindWings by Yara Marine Technologies (WindWings), more space and room to manoeuvre on deck ensures that conversions for the solution onboard bulk carriers are easier and possible without taking the ship out of service. There are, however, challenges. One of the biggest bulk carriers face in adopting the solution is ensuring WindWings do not affect port operations, but Cooper remains confident: "It is likely that ports will become more accommodating for ships with WAPs. Although not essential for the success of WindWings, we can see ports being flexible, for example by allowing vessels to always dock on one side rather than the other (to avoid the side where WAPs are installed)."

A key part of WindWings' design is its automated folding process and, for safety purposes, its ability to depower or fold in too strong wind conditions so as to not exceed the technology's predetermined leeway, heel angles and rudder angle maximums. Similarly, Anemoi Marine Technologies (Anemoi), a company specialising in rotor sails, tackles manoeuvrability in port via its patented rail and folding deployment systems, which allow rotor sails to move transversely/longitudinally depending on deck layout and lower to a horizontal position.

In April 2021, Anemoi announced that Oldendorff Carriers had joined one of its joint development projects (JDP) for dry bulk carrier rotor sail solutions; wind propulsion technology that uses the Magnus effect for propulsion whereby wind passing over the spinning rotor sail creates a pressure difference and a lift force perpendicular to the wind direction. Originally launched in November 2020 with project partners Lloyd's Register and Shanghai Merchant Ship Design and Research Institute, the JDP covers six different ship types in the tank and bulker segments, but the first to be addressed and in its final design stages is for a Newcastlemax owned by Oldendorff.

Bulk carriers are the focal point for the JDP partly due to their size, Anemoi Marine Technologies COO, Nick Contopoulos, explains: "One of the benefits of rotor sails is that they are suitable for most ship types and sizes. The main consideration relating to size is available deck space, which tends to make larger vessels slightly more favourable. Larger ships also tend to be on longer time charters with more predictable routes."

Rotor sails are proving to be a popular wind-powered choice for the bulk carrier sector, with Norsepower, in collaboration with Brazillian mining company Vale, announcing in May the first installation its rotor sails onboard a bulk carrier – the 325,000dwt *Sea Zhoushan*. Reflecting on the changing opinion of companies investing in WAPs, Yara Marine Technologies CSO Aleksander Askeland concludes: "A lot has changed just the last year. We now see much more action-oriented politicians and regulatory bodies. The winds of change are blowing. You can either try to fight it or you can set sail. It is survival of the fittest. Every major shipowner now works strategically at top level, on how to adapt. With 30% efficiency increase and emissions benefits we (WindWings) stand out as a very viable way forward for many shipowners." ■

GREEN SHIPS

IT'S NOT ALL ABOUT THE EEXI FACTOR

By **Jonathan Strachan**, newbuild and vessel conversion director, Houlder

Managing the transition to zero carbon shipping is not a simple process. From charterers looking for more efficient ships and banks seeking to improve the environmental performance of their loan books to the ever-present IMO regulatory targets, shipowners are being forced to act now. Shipowners need to be clear about which targets they need to meet and ensure that investment is targeted at the most effective solutions.

For example, compliance with EEXI doesn't necessarily improve a vessel's other ratings, it may not even significantly deliver actual performance improvement. The key to success will be to carefully consider all potential improvement measures, not just those required to meet EEXI. And owners need to start with the ship and not a list of technologies.

JONATHAN STRACHAN

Regulatory compliance

EEXI is due to come into force by 2023, after which a vessel will need to demonstrate compliance by its next IEEC survey. This only leaves a short window for a vessel's EEXI to be determined and, if not compliant, for suitable measures to be identified and implemented to improve the attained index.

Given that many ships already operate well below their design speeds, most of these will be able to achieve compliance by limiting shaft power without actually impacting on their current operation or fuel consumption. Only a small fraction of vessels will need to consider more significant power limitations or another means of compliance. We therefore see the IMO's second short-term measure, the Carbon Intensity Indicator (CII), as the key regulatory requirement that will drive the industry to reduce actual emissions through to 2030 and beyond.

Regulations, however, are not the only driver of shipping's decarbonisation. These new measures from the IMO only add to the government policy, pressure from lenders, and customer demand that are all forcing vessel owners and operators to find ways to reduce greenhouse gas (GHG) emissions from their fleets. Those that focus only on a vessel's technical efficiency – and fail to take action on actual emissions – risk losing business to 'greener' rivals and struggling to find finance from lenders. This is, therefore, an opportunity to improve vessel performance beyond the regulatory minimum and achieve a competitive edge.

Charterer pressures

Charterers continue to look at fleet competitiveness ahead of signing agreements and pressure is mounting. The possible carbon levies to cover the cost differential in opting for zero carbon fuels, together with transparent charter party agreements that account for carbon emissions, indicates a future where cargo interests call the shots in terms of vessel choice. This is clear within the Sea Cargo Charter, a global framework for assessing and disclosing the climate alignment of chartering activities. It establishes a common, global baseline to quantitatively assess and disclose whether chartering activities are in line with adopted climate goals. It therefore drives decision-making, impacting shipping operations and encouraging cleaner and greener operations.

The challenges of EEXI

As EEXI is a technical efficiency indicator, for many vessels real world carbon emissions will not be reduced by compliance with EEXI measures alone. Indeed, complying with it does not ensure that the other operational measures, such as CII, Sea Cargo Charter and Poseidon, are met, as these are operational measures of actual emissions. The key consideration here is that, while there is a general correlation, improving your technical efficiency score may not necessarily improve your operational efficiency.

Houlder's recent analysis of the bulk carrier fleet indicates that around 68% of vessels will need to undertake action of some kind to meet EEXI. Comparing design speeds with average operational speeds from AIS, these vessels tend to operate at speeds around 20% lower than the design speed. Assuming a cubic speed power relationship, a 50% power reduction would be achievable while still meeting these operational speeds. We estimate that this would allow the majority of non-compliant vessels to comply with EEXI without impacting on their current operations. On this basis, around 6% of the bulk carrier fleet reporting into the EU MRV database will need

more – either a more significant power limitation, or some other modification, or will be scrapped.

For tankers, around 56% (of those calling in EU ports) will require some action to comply with EEXI. For container ships, this figure is approximately 64%. Tankers on average look to operate at about 20% below their design speed, so we would also expect a large portion to be able to comply easily with an EPL.

Therefore, introducing a power limitation device to comply with EEXI limits may not impact the actual or operational carbon emissions. Focusing on EEXI also runs the risk of excluding other technologies or fuel sources such as green methanol, biofuels and carbon capture.

How to make smart decisions

Navigating the ongoing and changing regulations is key to success and using independent experts to analyse vessels ensures informed decisions are made to protect and improve operations. Having access to end-to-end support can assist in implementing these technologies in vessel designs and retrofits, and has significant value when understanding and responding to the decarbonisation challenge.

Houlder can assess an individual vessel's technical efficiency measures, such as EEXI, and its operational efficiency measures – EEOI or Annual Efficiency Ratio (AER). A detailed assessment can then be performed to determine the various improvement measures that can both solve the compliance issue while improving the ship's operational fuel efficiency. This allows shipowners to assess the options for improving efficiency and reduce carbon emissions, addressing both the technical and operational requirements. This includes looking at the specific operations of the vessel, optimising routing, just-in-time arrivals in port and keeping coatings clean.

Options available now

For passenger and cargo vessels, there are a multitude of effective energy efficiency adaptations with proven energy savings that can be deployed today to reduce fuel consumption and emissions; either for regulatory compliance or to demonstrate environmental credentials to potential charterers. Many of these measures can be deployed as retrofit solutions, such as hull appendages to improve propeller efficiency, high-tech anti-fouling coatings, and innovative rudder designs, as well as innovative technologies like hull air lubrication and wind assisted propulsion systems. There are also a range of modifications that can be made to the onboard electrical and mechanical systems that can achieve significant energy efficiency improvements. Checking the vessel route and vessel arrangements can determine whether wind propulsion is a viable option too.

If you are planning on fitting a power limiting device to comply with EEXI requirements, consider propeller efficiency at this lower speed. Also check if a change in bulb helps to improve efficiency further at this lower speed and consider other flow improvements from a propellor boss cap fin (PBCF), rudder bulb, or Mewis

PROPELLER BULBS, SUCH AS THE MEWIS DUCT, CAN IMPROVE EFFICIENCY IN THE EVENT OF ADOPTING POWER LIMITING TECHNOLOGY

Duct. With these modifications it is worth conducting analysis at a range of draughts and trims to ensure the delivery of efficiency improvements across the vessel's operational conditions.

The reality is that there is no single best solution to the energy efficiency challenge. While proven opportunities to improve efficiency, minimise fuel consumption, and reduce emissions exist in abundance, it requires careful analysis to determine how they can be packaged together for greatest effect – to achieve the best return on any investment. Owners that go beyond the minimum regulatory requirements are well placed to reduce operational costs and capitalise on market opportunities.

Given the complexities involved with major retrofit projects, assessing the costs and benefits of these measures early on allows shipowners to understand the potential impact of each option in terms of fuel consumption reduction and emissions improvements. It is not just about the technical measures to meet EEXI but also the operational efficiency measures to meet EEOI and AER, and assessing how to improve efficiency and reducing carbon emissions for the vessel across both.

Having access to end-to-end expert support can assist in identifying and implementing the right technologies for vessel designs and retrofits, and has significant value when understanding and responding to the decarbonisation challenge. The chosen solutions need to be both technical and operational to achieve commercial success and enable the business to remain competitive in a changing market. Examining a vessel's operational profile alongside its technical features allows for more accurate estimation of achievable benefits of retrofits or adaptations. It doesn't have to be drastic technological changes that make a difference on a vessel but it does take knowledge and experience to know the right steps forward. ■

GREEN AMBITION INSPIRES IOM REGISTRY

By **Isle of Man Ship Registry**

Pioneering research into green propulsion technology is underway across the maritime sector in an effort to decarbonise shipping and find viable alternative marine fuels. The Isle of Man Ship Registry (IOMSR) believes flag states have an important role to play in promoting green shipping by creating a pragmatic regulatory framework which rewards innovation and helps the industry meet the International Maritime Organization's environmental targets.

In April 2014, the registry unveiled its Green Fee initiative, offering registration discounts of up to 25% to shipowners adopting energy efficient ship designs that reduce fuel consumption and air pollution. Seven years on, businesses face difficult choices as they strive to achieve the IMO's goal of reducing greenhouse gas emissions from shipping by at least 50% by 2050 compared to 2008 levels.

Bill Liddell, a senior surveyor at IOMSR, says some shipping companies are reducing emissions by moving from 'black' emission-unfriendly hydrocarbon fuels to 'grey' transition fuels such as LPG and LNG. Others are moving one step further by switching directly to 'blue' biofuels and other low flashpoint fuels. As ever the case in shipping, there is trade off to be had – "Blue" biofuels and other low flashpoint fuels have less energy per unit volume and therefore efficiency and power are affected.

Getting towards 'green' fuel technologies using hydroelectric, wind-electric or nuclear energy to synthesise hydrogen rich fuels is the ultimate goal, since truly green fuels have the smallest carbon impact.

He says: "It's a massive arena and everyone is vying for your business. Shipowners are hesitant about making investments because there are so many potential routes to take. Do you go from black fuel straight to blue fuel, or perhaps transition to grey fuel now to start reducing your impact immediately and go fully green when it is a viable option? Whichever you choose it involves capital expenditure.

"A huge amount of work is underway to explore the various fuel technologies. Engine manufacturers are developing new solutions and designs to take account of the different fuel types and their combustion characteristics, some of which have not yet been certified for use. There are some genuine concerns within the industry that there is a lack of a robust regulatory framework, standards and guidance in the development and use of fuel technologies and in many instances the necessary distribution and infrastructure are not in place in sufficient volume to meet demand.

"The biggest decision at the moment for companies is what approach to take and how to achieve it. If your company has committed to reducing its carbon impact by 50% in the next five years, what is it going to do now?"

BILL LIDDELL. SOURCE IOMSR

BW collaboration

Retrofitting vessels to run on liquefied petroleum gas (LPG) is one option available today. Thanks to ground breaking work carried out by IOMSR alongside Oslo-listed shipping company BW LPG, owners of mature gas carriers are also able to adopt this approach and see GHG/carbon emission reductions and return on investment immediately.

Prior to March 2020, gas carriers designed and built to the 1983 International Gas Carrier code (as amended) were only permitted the use of liquefied natural gas (LNG) as a fuel. IOMSR worked with BW LPG and partners Wärtsilä Gas Solutions, MAN Energy Solutions and DNV, to secure the granting of a design equivalence by the IMO, allowing the use of LPG as a fuel.

The Very Large Gas Carrier (VLGC) *BW Gemini* was the first of BW's nine Manx registered LPG vessels to be retrofitted for this fuel, setting a precedent in the industry and enabling IOMSR to issue the first flag acceptance of a modification to use LPG as fuel for older gas tankers.

Mr Liddell says: "The legislation those particular ships were built to didn't permit the use of LPG as fuel, so we had to get a design equivalence standard of safety to be able to do that.

"I do believe more companies will look to go down this route because retrofitting their engines is something they can do now. The work requires the ship to be out of service for approximately two months and can be done during a drydock period with suitable preparation.

"This approach doesn't suit every vessel, but it does work for gas carriers as they already have the safety

and control systems in place to handle a liquid gas cargo. Other types of ship would have to install it making it a far more involved (and expensive) process."

IOMSR believes the industry has a collective responsibility to respond to the climate emergency by taking action to effect real change. Last November, the registry became the first flag state to join the Getting to Zero Coalition, an industry-led alliance working towards decarbonising the international maritime shipping sector. The Coalition, whose members include more than 120 organisations from the maritime, energy, infrastructure and finance sectors, says the development and deployment of commercially viable, deep-sea zero-emission vessels by 2030 is key to achieving IMO targets.

Mr Liddell adds: "Fuel choice needs to be matched to the vessel type and the anticipated service of the ship. You've got to have a very open mind in terms of what your solution will be.

"There seems to be a real mix of approaches. Some businesses are taking action, some are weighing up what it will cost and the pros and cons, and others are just holding off until there is a bit more certainty on the direction things will take."

Without defined recording parameters, without defined efficiency measures, without a uniform and transparent data exchange structure throughout the entire fuel chain, how can you reliably compare the improvement one small change in any part of that chain makes relative to another?

How do you compare one ship type/size efficiency relative to another or evidence you are actually achieving theoretical or modelled emission reductions?

How will you prove you are meeting your company's declared carbon reduction goals and prove you are meeting the internationally agreed limits indicated on your vessels statutory certification?

This area in particular needs more urgent scrutiny by the regulators. Industry is crying out for suitable guidance in order to structure development pathways and properly reasoned arguments to raise capital investment (any change, by definition, comes at a cost).

It's hard to see where one piece of a jigsaw fits without an overall picture to look at – carbon impact starts in the ground, finishes in the atmosphere and literally affects every process in-between.

NOT ALL DIGITAL TWINS ARE ALIKE

By **Nick Bialystocki**, SME Ship Performance, Stratumfive Ltd

In February this year, the Royal Institute of Naval Architects hosted the Full Scale Ship Performance Conference. As StratumFive's subject matter expert in ship performance, I considered the immediate demands for GHG emission reduction and the need to promote efficient operation.

Much of the conference focused on the advantages of developing Digital Twins. Sophisticated networks of sensors and analytical tools can be used to develop digital models to promote asset health, optimise performance and predict/prevent failure across an increasing range of systems. The knowledge derived from these twins will inform the operation of remote/autonomous systems.

The original twinning concept was presented in 1993 by Prof. David Gelernter, from the Computer Science department at Yale University, in his book 'Mirror Worlds: or the Day Software Puts the Universe in a Shoebox — How It Will Happen and What It Will Mean'.

In 2010, NASA adopted the expression Digital Twin and it has since been applied in various industries including agriculture, engineering, medicine and manufacturing. In order to simulate how a system will behave, and assist the operator in taking decisions, three main components are required:

1. Having a physical product.
2. Building a digital/virtual product.
3. Creating connections between the two products, i.e. simulations.

A virtual asset can be built, representing a physical process, product or service. This virtual asset enables optimisation of the design and/or the operation of the system in real time through comparisons with the physical asset and the ability to run simulations virtually before execution on the physical asset. A comprehensive set of smart sensors are essential to accurately collect information for a mathematical model that can take the measured data into account and construct the virtual asset.

Whilst the advantages of this environment are demonstrable they do come at a cost many in the industry have not been prepared to finance and trial.

A Performance Twin

In contrast to the above, readily available data which, in most cases, requires no installation onboard, can be used to establish Performance Twins. The twin is built using historical data, reported/streaming data and a mathematical model. Whilst this model will not offer the full range of comparisons, simulations, optimisations and predictions of a Digital Twin, it does permit a focus on the immediate concerns of voyage optimisation, fuel efficiency and GHG reduction. The benefits derived may also lead to the faster adoption of the system of sensors needed to develop full-blown virtual assets.

The Performance Twin model is developed using a range of comparison 'markers' such as vessel type/size/builder and ship specific parameters including hull shape, main engine specs, drydock dates, etc, to create a reference virtual asset. Historical data, which can include a combination of tracking, manual and streaming data, can then be applied to the reference virtual asset resulting in a Performance Twin.

In order to measure the relevance of the available data obtained for building the Performance Twin, three grades of 'match' were adopted; highest (i.e. sister ship characteristics), high and good (representative markers). This flexibility allows a relevant match to be made even if hull and main machinery specifications vary.

Within the limitations of the model, development performance comparisons can be made with the physical asset and simulations conducted with the virtual asset before execution on the physical asset.

FIG. 1: PERFORMANCE TWIN MODEL

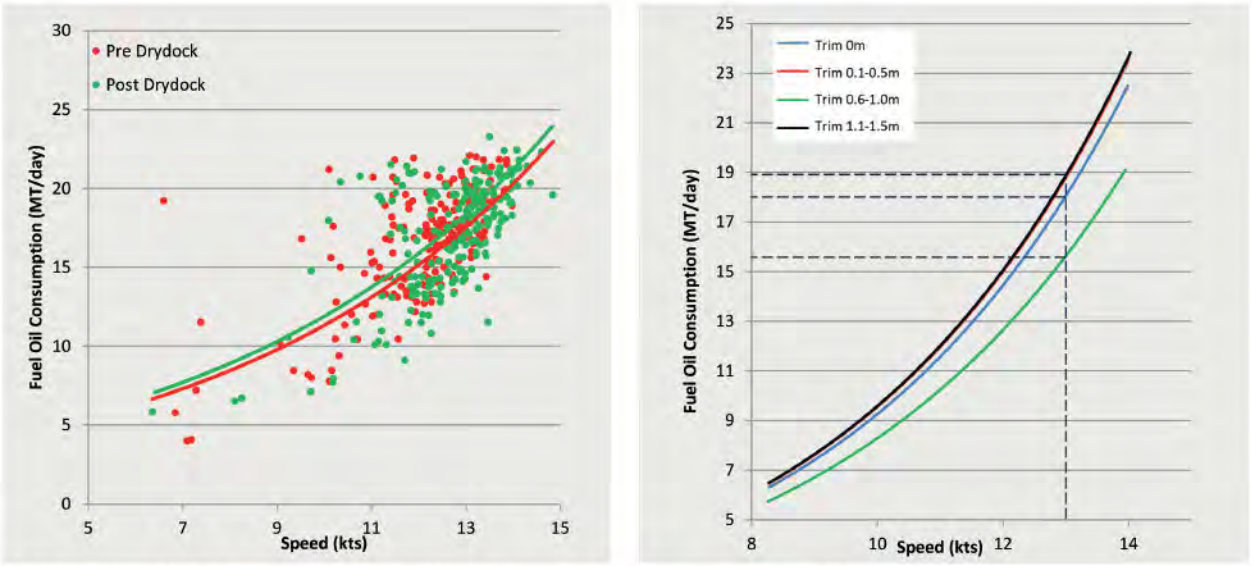


FIG. 2: PERFORMANCE TWIN APPLICATION OF HULL CLEANING EFFECT (LEFT) AND TRIM OPTIMISATION (RIGHT)

A solution such as Podium, StratumFive's Voyage Informatics Platform (VIP), can be used to develop the Performance Twin.

Performance Twin applications

Performance Twins provide actionable operational insights in areas such as:

1. Accurate estimation of the fuel consumption and speed curve, which can assist the shipowners in benchmarking vessels, carrying out performance comparisons, and estimating how the vessel will behave in different environmental conditions.
2. Evaluation of the effect of hull cleaning/drydocking on the performance of the vessel. This can assist the owners in taking a decision about the timing to carry out hull cleaning and the potential savings due to improving performance. More so, it enables the feedback analysis when after cleaning of the fouling from the hull, the owner will be able to verify the effect in comparison with a benchmarked Performance Twin. (See Fig, 2)
3. Assessing the twin vessel performance in various trims, which can help the ship operator in recommending the master with the most effective trim. This application, similar to the hull cleaning, enables the owners to continuously monitor the fuel efficiency improvement due to running the vessel at an optimised trim. (See Fig, 2)
4. Improving the weather correction factors by comparing the real and the twin resistances of vessels, this enables to improve the accuracy of the model.

Twelve months of data was used in the case study presented at the RINA conference. Based on owner's needs the analysis period can be tailored, but the most robust model is likely to be developed across a drydock cycle. It is worth noting the Performance Twin model is designed to update the output performance curves for the period selected in the Performance Twin module within Podium.

Limitations and future work

The model produced was tested for real data sourced by a combination of ship's noon report (fuel oil consumption, draft, etc) as well as online ship's position and calculation of speed over ground as well as speed corrected to environmental factors i.e. wind, wave and current. It is anticipated an increase in streaming data in lieu of using noon reports will improve the Performance Twin model.

The test included NO filters and in Fig. 2 one could see a significant spread of data points. Data cleaning was not carried out in order to test the model accuracy to its limit. Further work is to be done, which includes smart filtering of the data to reduce errors.

Other Digital Twin related products are found in the industry solving specific problems, such as CFD based programs to estimate the optimum trim. The uniqueness of Podium as a VIP is the scope of performance related data that is collected and applied to the model calculation. This ability to use all the available data reduces the impact of outliers and errors to deliver the best accuracy. In other words, the model is not setting a minimum data that the owner should provide (for example if by noon report or by wired sensors) but is designed to extract the most value to the ship owner/operator in any case, noting of course that the more quality data the better the accuracy and performance twin prediction.

Summary

A Performance Twin shares some characteristics with a Digital Twin in terms of development, operation and insight, but it is by no means identical in terms of accuracy and scope of actionable data insight. The Performance Twin does have advantages with respect to cost and time needed for implementation, permitting a more immediate and certain return on investment. These results and a better understanding of what is possible with data may make the remaining steps to a full Digital Twin that much easier. ■

SHIPBUILDING TECHNOLOGY

FRONT LOAD EARLY PART OF CRUISE SHIP DESIGN TO IMPROVE OUTCOME

By **Kari Reinikainen**, Correspondent

As the size of cruise ships has grown, newbuilding projects have become increasingly complex, which calls for a rethink in how the early stages of the design process is organised, says Marjo Keiramo, whose doctoral thesis 'Pathways of the Creative Journey – the Significance of A Cruise Ship Concept Design' was accepted at the Aalto University in Helsinki in the spring. The work suggests front loading the design process, involving close cooperation between various partners and a clearer understanding on the focus of each stage of the process.

When the first purpose-built cruise ships entered service in the early 1970s they barely measured 20,000gt, whereas today several existing ships and newbuildings have a gross tonnage more than ten times that figure. A major vessel today comprises more than nine million parts and requires more than 150,000 assembly tasks. At the end of the concept design stage, only 5% of the work has been done, yet 70% of the cost has been committed. This involves a high risk, which is even greater in the case of prototype vessels.

Keiramo suggests that the present generic timeline-based approach (Fig 1) could be replaced by one with three stages before the basic design stage – dream, ambition and creation (Fig 2).

Dream, ambition, creation

At the dream stage, a small number of experts, mainly from the owner, discuss preliminary specifications of the new ship. During the subsequent ambition stage, the output of the previous phase would be enhanced through understanding of the overall product implementation with inputs from technical, engineering and architectural specialists introduced in the picture. Finally, at the creation stage, a large number of experts from various disciplines would be brought in to create a fundamental design concept.

The principal novelty of the approach Keiramo proposes is a more detailed sequencing of the various stages of the design work, which is often a difficult process. It allows monitoring of work status continuously between several teams in a multi-professional environment. Close collaboration between the various teams is of major importance in the new approach.

Keiramo notes that it is important to bear in mind that many new ideas do not emerge in the minds of designers, but rather of those that are involved in face-to-face contact with customers and other stakeholders. Therefore, collaborative partnerships are an elementary cornerstone of the new approach and this requires trust between the various partners involved in the design project of a new cruise ship.

It is not only the scale of cruise ships that is posing challenges to the cruise industry and the yards that build these ships, Keiramo notes. "We need to know

FIG 1. CLASSICAL GENERIC TIMELINE FOR A PROTOTYPE VESSEL

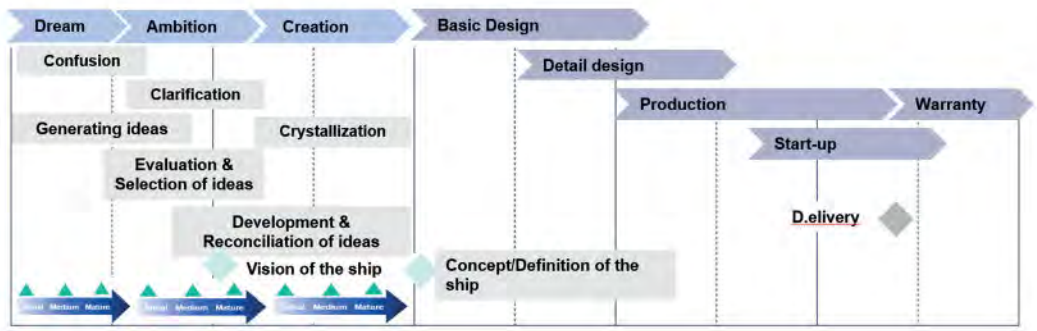


FIG 2. NEW FRONT-END PROCESS ARRANGEMENT DAC WITH 3 'C'S

what will be needed in the future. Environmental matters will certainly continue to increase in importance. Then there are questions like what benefits does the cruise industry bring to the regions where the ships sail. Also, millennials and younger generations are becoming an increasingly important group of consumers," she tells *The Naval Architect*.

The cruise industry has traditionally focused heavily on the baby boomer generation, roughly those born between 1945 and 1965. However, younger generations are already an important part of the business of the cruise industry and it is of vital importance to understand what they expect from a cruise holiday. This again affects the design of ships.

Partnerships and collaborative networks

At the same time, the world is entering the so-called sixth wave of industrial development, in which intelligent and resource efficient technologies are taking over from digital communication as drivers of change. Materials, energy production and its distribution are emerging as the prime fields of technological development, while advances in computing are increasingly focused on integrating human nature and technology.

"Taking into account such a complicated structure of innovation as the cruise ship is and the high demand for breakthrough solutions, generating meaningful new ideas for lucrative concepts in collaborative partnerships and innovative networks is becoming more important than ever," Keiramo comments in her thesis.

Passion is another crucial aspect that Keiramo says all those involved with the early part of a newbuilding project should be able to bring to the table as well. Designers need to be able to shine, as she puts it, and it is important to make sure that during even busy times the project team does not slow down the concept design work – should this happen, it can lead to a snowball effect that results in bad compromises, not to mention cost and timetable overruns.

Keiramo's thesis offers a wealth of information on cruise ships and shipbuilding, drawing upon her extensive experience during two decades working for Royal Caribbean Group, Baltic Yachts and the Meyer Turku shipyard.

She is the fifth woman to complete a doctoral degree in the field of naval architecture and marine engineering in Finland. Her doctoral dissertation is the first to deal with with the conceptual design of cruise ships. The dissertation is currently being adapted into a marine engineering textbook for students at Aalto University. ■

THE FORAN APPROACH TO THE INDUSTRY 4.0

By **Dr Rodrigo Perez Fernandez**, SENER

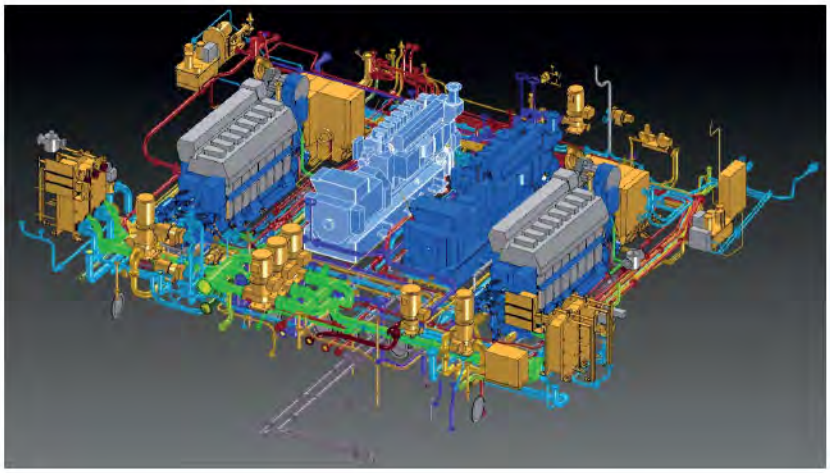


FIG.1: DYNAMIC HIGHLIGHT EXAMPLE IN AN AHTS ENGINE ROOM

Ship design has varied extensively throughout history as it was shown in the April's edition of *The Naval Architect* magazine. Over the past 40 years, CAD/CAM/CIM tools have progressed from mainframe computers to tablets, from independent programs to fully integrated software packages, and from large shipyards to companies of all sizes.

Nowadays it is unimaginable to work without using CAD in shipbuilding: ease of design with design rules embedded, speed of design, use and reuse of information, etc. It is expected that in the future CAD tools will advance further and allow greater information management through new improvements. And some of these new improvements can be seen in the latest version of FORAN, V80R4.0, a new FORAN release launched in May. There are several scenarios of improvements explained below, with even more planned for the next few years.

To give some background, FORAN is a CAD/CAM/CIM tool developed by SENER that is used in the design and construction of vessels and marine structures. First launched 50 years ago, FORAN has always been at the front end of the technology and is currently licensed at more than 150 shipyards and design offices in 40 countries. It is the only software of its kind on the market, as it encompasses every aspect of design in a fully integrated manner and because it is used at every stage of the design and production of a vessel.

Since the launching of the release V80R3.0 in late July 2019, SENER has continued improving the FORAN system in all its disciplines. The development effort has resulted in a great number of improvements in the entire system, incorporating new technologies such as artificial intelligence (AI). This paper introduces a few of the new capabilities available in the release V80R4.0. With regard to digital revolution capabilities, SENER has also developed the FORAN Assistant, a new AI-based tool for online assistance: https://foran-assistant-prod.eu-de.mybluemix.net/.

Visualisation engine

Modules with 3D scene have a new and modern visualisation engine with several new functionalities. Compatibility with former visualisation mode is also available.

The interaction with the application is made more user friendly with this new visualisation engine. Take, for example, the dynamic highlight (see Fig. 1), whereby selectable objects are automatically highlighted when the mouse is hovered over the scene. Or the new selective mode, which highlights the intended objects, making transparent those elements that have no interest but are useful to locate some objects. So, the hidden objects are visible in a ghost visibility mode. This option, as well other ones, is configurable in the view preferences. With the new navigation system, the designer can navigate through the scene without activating any specific mode. This mode is integrated with the mouse wheel in a very intuitive mode and it is not necessary to switch between navigation and selection modes. Navigation is always enabled when working in 3D scenes.

The visualisation engine is compatible with the most contemporary graphic libraries such as Vulkan, DirectX 12 or OpenGl 3.0, making application hardware independent. There is also a new user preferences file editor, where the visualisation preferences can be edited in an extensive, easy and comprehensive dialog, with the values stored in preferences files. Tools for manipulating the objects, like routing aided tool or interactive movement of control points, have been improved and integrated with the visualisation. There is as well a transparent mode for real limits, where the real limits display is replaced by the new transparent mode giving a more realistic visualisation.

It is also possible to activate ray tracing mode (see Fig. 2) for detecting shadows and dark places. This is a new rendering mode, based on raytracing, and allows photorealistic images by adding shadows and/or

reflections to the scene, albeit at the expense of more processing time (so it is not recommended as a normal working mode with big scenes).

Initial design phase

FORAN Initial Design comprises the Hull Forms, General Arrangement and Naval Architecture calculations, all integrated with the other design disciplines in FORAN, which ensures data integrity, fast propagation of changes, multi-user access and the reuse of information in later stages.

In the V80R4.0 a new set of improvements have been developed, including the domestic Chinese stability criteria for river and seagoing fishing vessels, automatic generation of damages, additional requisites for Australian stability criterion, and SOLAS stability criteria updated to 2020. There is also the possibility of using friction coefficient in dynamic launching and parallel force calculations in launching and floating calculations, dredging ships stability criteria (DR-68 and Spanish Maritime Directorate) or, the stability criteria MSC.415(97) for ships engaged in anchor handling operations, towing and escort operations and lifting operations.

Structure Subsystem

FORAN Hull Structure provides a complete solution for definition of the 3D model of the structure, and for the automatic generation of all information required for manufacturing.

The V80R4.0 has introduced new features to improve user experience of applicability management in series projects, 3D jig model drawing (base plates, templates parts and base plane), unlimited number of drawings based on a set of different templates, and new context to preview cutting sequences: CNC viewer, new labelling concept for display and hide side in marking labelling pattern, improvements in welding visualisation or new architecture for post processors to generate cutting sequences.

Machinery and Outfitting Subsystem

FORAN Machinery and Outfitting continues the design process by incorporating all aspects related to equipment, piping, HVAC ducting and auxiliary structures into the same project-centric database used for the ship structure.

A single tool manages the equipment, piping lines, HVAC ducts, auxiliary structures and supports. Finally, all information for fabrication and assembly is generated automatically, including fab sketches, isometrics, drawings and reports. Some of the new functionalities are advisory of the impact in series projects due to modifications of some elements, impact assessment report due to design changes, new context for pipe isometric edition and drawings, or management of variable-radius bended pipe pieces and instruments with several connection points.

The possibility to add dimensions in FDESIGN spool drawings has been implemented. A new area in drawings template permits configuration of the dimensions needed in that area of automatic drawing. Part lists can now display bending information, installation coordinates and verification of local coordinates. New options for labelling spools drawings have been added to label.

Electrical Subsystem

FORAN provides advanced functions to manage all the relevant aspects in design and production of electrical systems. In particular, it includes facilities to create electrical diagrams, to model electrical equipment, to create 2D or 3D equipment and cableway layouts, to calculate cable sizes, to route cables, to define cable terminations, to manage instrumentation and control signals, and to generate different types of reports and drawings.

The modules included in the FORAN Electrical Subsystem have integrated the use of spaces or compartments defined so far in the Basic Project Design module, replacing the former use of the "ship compartments" which were managed in past versions exclusively within the electrical modules. Thanks to this, the system now integrates the assignment of electrical devices to compartments according to the new approach used in the rest of the Outfitting and Machinery discipline. The changes consist of the substitution of the way the former compartments were used in dialogs, filters, properties and reports, by accessing the new source of information. A basic dialog for edition of the compartment tree and their properties, sharing the same information as that managed in General Arrangement (GA), is provided as well. Besides, the "ship compartments" defined in the Electrical Subsystem in projects of previous versions

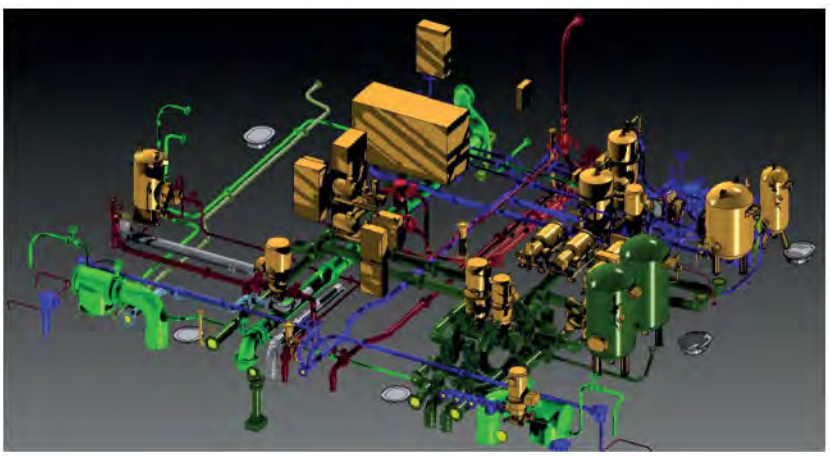


FIG. 2: RAYTRACING DISPLAY MODE. IT IS POSSIBLE TO ACTIVATE RAY-TRACING MODE FOR DETECTING SHADOWS AND DARK PLACES

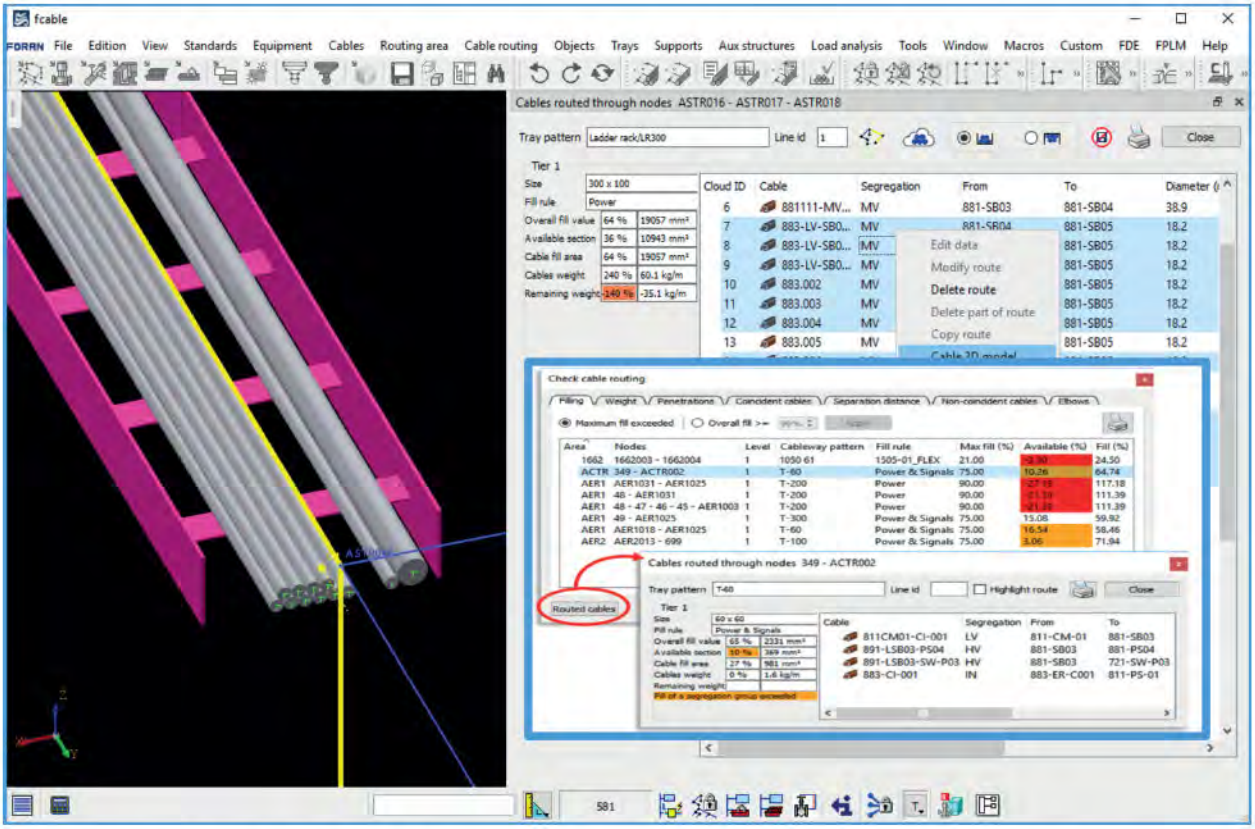


FIG. 3: FUNCTIONALITY TO VISUALISE 3D MODEL OF CABLES ON DESIGN REVIEW TASK. 3D MODEL OF CABLES ROUTED IN A TRAY SEGMENT

are preserved and migrated as GA compartments. All this results in the elimination of the duplications that previously existed and in the complete integration of the concept of space or compartment throughout the system, both in its geometry and in its logical attribution.

Designers will benefit from a better and more intuitive graphic user interface in case of the cable tray fitting library and the insertion of fittings in the 3D model. Besides, they will benefit from new modelling options that will enhance the object creation possibilities as well as their productivity, as for example with the functionality to visualise the 3D model of cables as a design review task (see Fig. 3).

Electrical design provides new functionality to calculate the voltage drop of an electrical circuit from the power supply equipment to the terminal element, considering all the cables and intermediate equipment involved. Furthermore, new possibilities have been included for the automatic sizing of cables according to criteria such as maximum electrical current allowed according to several installation methods, voltage drop or short-circuit current.

These new features will be very useful for the cable design in early stages of the project in several aspects such as saving time due to the inclusion of predefined conductor resistance ISO/IEC standard data, increasing the types of calculations currently offered by the FORAN system, and allowing the designer to be aware of wrong cable sizes not supporting either the voltage drop allowed or the electrical load demanded in an electrical circuit from end-to-end.

CAD & PLM Integration

FORAN-PLM advanced integration is a solution that offers efficient sharing of information, processes, systems and databases during the design, production and operation of ships. One of the features linked to the PLM Web viewer integrated in FORAN is the possibility to read elements by dragging and dropping them on the scene from this viewer.

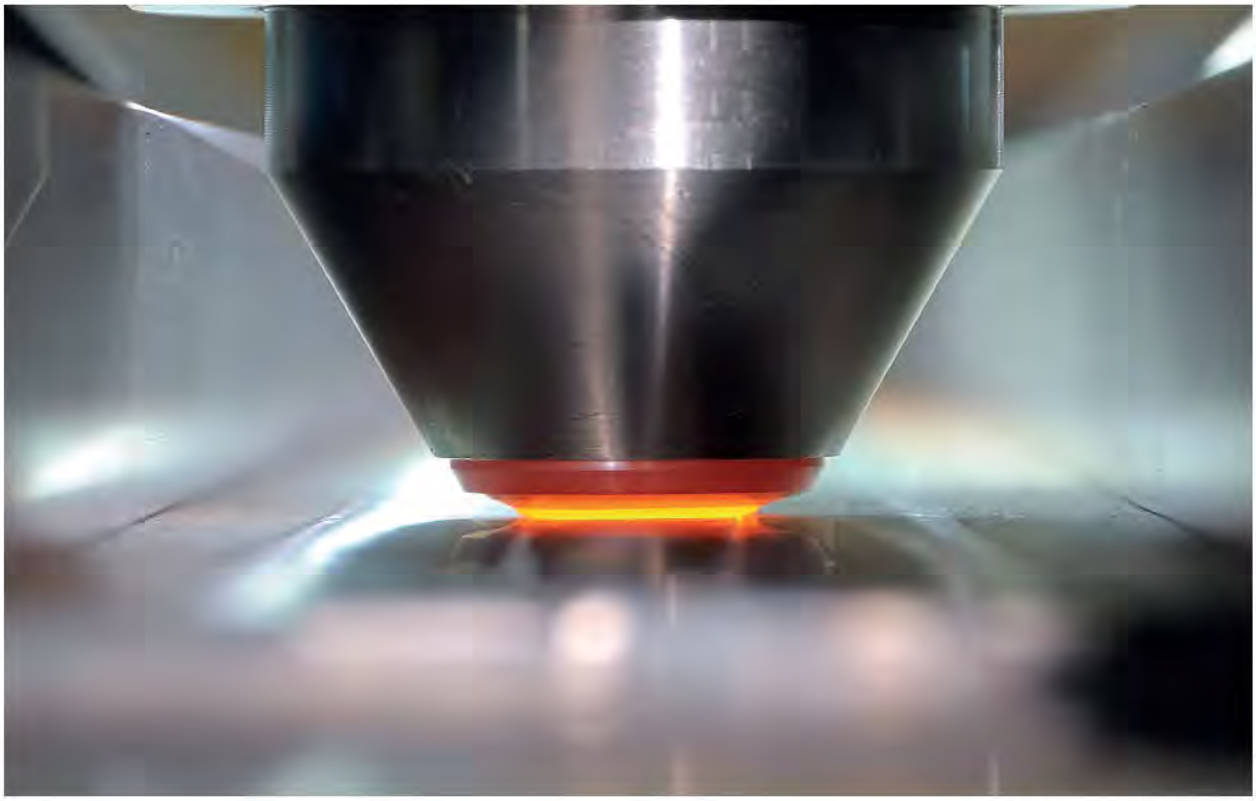
Several improvements related to Engineering Change Notes (ECNs) management have been implemented, in order to cover the full process of changes in a series project, from the analysis of the change and its impact assessment in the PLM where the ECN is born and ending with the change embodiment in FORAN and the publication of the change to the PLM system.

FORAN-PLM Teamcenter Integration will use Standard Teamcenter external application integration API, to communicate FORAN items to Teamcenter in a direct way. This integration can work with the latest Teamcenter version and it is fully functional with current FORAN capabilities. It can be fully adapted to any kind of Business Model available in client. A plugin, FORAN-PLM FWSI, allows publishing to certain Windchill contexts: Repository, Library and, also to ProjectLink ones.

Finally, with FORAN V80R4.0 SENER maintains its position as a leading provider of integrated solutions for shipbuilding and the offshore industry, continually reinventing and providing customers with solutions to fulfil their needs. ■

INNOVATIONS IN FRICTION STIR WELDING FOR MARINE APPLICATIONS

By **Stephen Cater**, RESURGAM project leader, The Welding Institute



SOURCE: THE WELDING INSTITUTE

Friction Stir Welding (FSW) is a solid-state welding process invented by The Welding Institute (TWI) in 1991 and subsequently widely used for the fabrication of structures requiring high strength, lightweight, fatigue resistant joints. The process was originally developed for joining aluminium, as this is considered a difficult material to weld, and was subsequently developed for other hard to weld metals such as magnesium and copper. FSW was quickly adopted as a fabrication technique for spacecraft, trains, shipping and automotive components, as well as electronics assemblies and consumer goods, all applications where aluminium joints needed to be made that were strong, tough, fatigue resistant and lightweight.

The development of tools sufficiently strong to stir steel meant that introducing FSW to steel was a challenging undertaking. However, small-scale laboratory testing showed that the quality of friction stir welds in steel could be exceptionally good and thus the quest for industrially useful FSW tools for joining steel was deemed worthwhile. Such tools are now being introduced to the market and work is underway to identify and exploit the many benefits of the process. An area where FSW in steel is likely to see early use is in shipbuilding and shiprepair, two areas in which TWI is actively engaged to develop the technology as part of the RESURGAM project. This is a three-year, EU-funded, multinational research initiative to develop the equipment, processes and qualification routes needed for fabricating ships and conducting underwater repairs of steel structures using FSW.

How does FSW work?

Conventional fusion welding processes used for the fabrication and repair of marine structures are essentially a casting technique. The two components to be joined are brought together and energy applied, typically in the form of an electric arc or laser beam, to cause the metal at the region of the joint to melt and coalesce. As the energy source is removed this molten weld pool freezes and the previously separate components are now a single piece. When done well, this produces a strong, tough joint but there are potential problems, including:

- Structural distortion arising from the thermal energy input and the phase change from solid to liquid and back to solid.
- Changes in metal properties due to the creation of a cast microstructure in what was previously typically wrought plate.
- Changes in materials properties due to the addition of a filler material, or the boiling off or segregation of the original alloying elements.

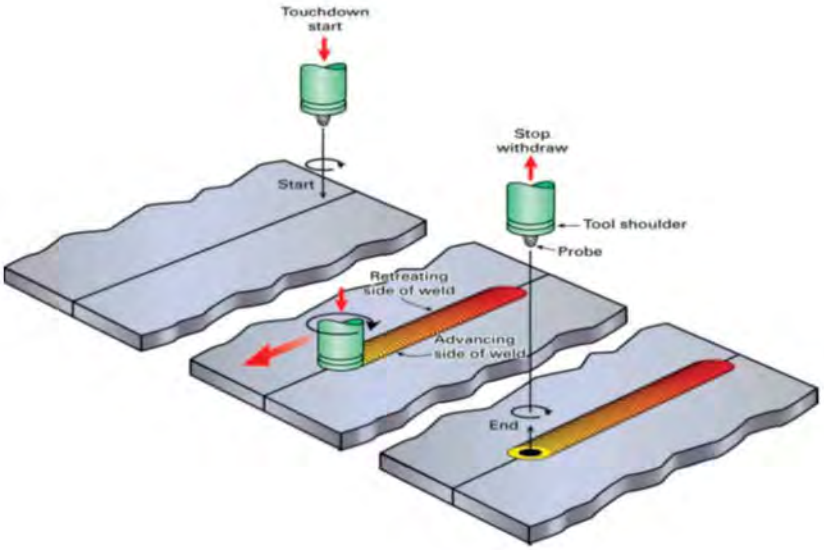


FIG. 1: THE GENERAL PRINCIPLE OF FRICTION STIR WELDING

- The potential for generating defects such as porosity, undercutting, lack of penetration and inclusions.

These issues can be overcome, but require the development and implementation of both specific technical measures and adherence to good working practices, e.g. Welding Procedure Specifications, along with appropriate quality control and post weld testing regimens.

In contrast, FSW is fundamentally a technique in which the components are never molten – not unlike blacksmiths heating up steel and hammering it together. To make a simple butt joint using FSW, the two plates to be joined are placed side by side and the rotating tool is lowered and brought into contact with them at the joint line – as shown in Fig. 1. The rotating tool generates frictional heating and this softens, but does not melt, the metal. As the metal becomes soft and plastic, the tool is driven into it until it is fully embedded to the tool shoulder and then traversed along the joint line. The tool continues to heat and soften the metal immediately ahead of it, and the rotary action of the tool sweeps metal around it and across the joint line, uniting the two pieces of metal as one. At the end of the weld, the tool is extracted.

The benefits of FSW arise primarily from:

- The elimination of melting in the joining process.
- The generation of a forged rather than cast weld microstructure.
- The elimination of human variability and skill from the welding process.

Considering these in more detail, the elimination of melting brings about a significant reduction in structural distortion, and enhanced health and safety benefits as there are no molten metal or fume hazards. Additionally, the process is far less energy intensive. The absence of a liquid metal weld pool also frees the process from gravitational effects and constraints; welds can be performed vertically (3G) and even overhead (4G) just as easily as a flat, horizontal weld. A further benefit is that FSW can also be performed under water and has even been demonstrated to be effective when performed in oil.

The mechanical, forging nature of FSW produces a fine grained, wrought microstructure rather than the more typical cast microstructure of fusion welding. This can be seen in Fig. 2, which shows a multi-pass arc weld in a 20mm thick carbon steel plate. The arc weld was made using a V preparation that was then filled by 38 sequential arc weld passes. These have produced a cast microstructure with large columnar grains and a large heat affected zone. A FSW tool was then passed through the upper portion of the weld, creating a very fine grained, forged microstructure with a much smaller heat affected zone (HAZ). The microstructure in this FSW region is very similar to that of the wrought parent metal and, unsurprisingly, has very similar mechanical properties.

Fig. 3 shows a typical metallographic section through a friction stir weld in 6mm thick DH36 steel. The weld shows full penetration and no significant undercutting, with no visible internal defects such as voids, shrinkage cracking or segregation. The HAZ is small and the weld has a fine grained, equiaxed microstructure similar to

FIG. 2: A METALLOGRAPHIC SECTION THROUGH A MULTI-PASS ARC WELD IN 20MM THICK CARBON STEEL, WITH THE WELD CAP RE-PROCESSED BY FSW TO SHOW THE DIFFERENCE IN WELD MICROSTRUCTURE

FIG. 3: A METALLOGRAPGHIC SECTION THROUGH A SINGLE PASS FSW IN 6MM THICK DH36 STEEL

the parent plate. As no filler metal is required for a FSW, the alloy composition remains unchanged and the costs of purchasing, storing and administering filler metals is eliminated from the welding process.

Friction stir welding is a mechanised process, suitable for automation or robotisation. In its simplest form, it can be undertaken using a milling machine. The process is thus not dependent upon the skill of individual welders and so reduces process variability, allows for 24hour operation, can be performed in hazardous environments and permits the use of in process statistical control and automated non-destructive testing/quality assurance techniques.

Potential disadvantages of the FSW process are the requirements that the work pieces need to be firmly clamped to prevent them moving apart when the FSW tool is plunged into the joint line, and that the weld must be supported from beneath during welding to react the applied force of the friction stir welding tool. These are not difficult problems to overcome, but do need to be recognised. Thought also needs to be given to means of eliminating the exit hole left when the tool is extracted: this is typically achieved by using a run off tab.

Weld geometries

The physical, forging nature of FSW places some constraints on the weld geometries that can be achieved as the two faying surfaces are required to be brought into close contact and filler metal is not available to make up any significant gaps. That said, a wide range of joint geometries has been achieved in light metals with typical examples shown in Fig 4.

An example of a radiused corner fillet weld made by this technique is shown in Fig 5. Here, two 8mm thick plates of AA6082 have been joined using opposing passes of a FSW tool which simultaneously joined the plates and forged the radius into the plasticised metal before it cooled. Though the process is fully solid state, techniques are available (AdStir) to add filler metal to the weld if required to build up the fillet or add metal to compensate for poor fit up of the plates being joined.

In time, these techniques may be developed for welding in steel: any limitations are not imposed by the process itself but by the need to develop tools that are sufficiently strong and robust enough to stir the steel.

Technology transfer to steel

FSW has been a major enabler in the development of high speed, aluminium hulled vessels, particularly fast ferries and naval patrol craft. The welds have proven to be strong and stiff, with excellent fatigue and corrosion resistance. Civilian vessels also utilise FSW, often for the modular build of aluminium decks and superstructure components on a steel hull to provide strong, stiff but lightweight upperworks.

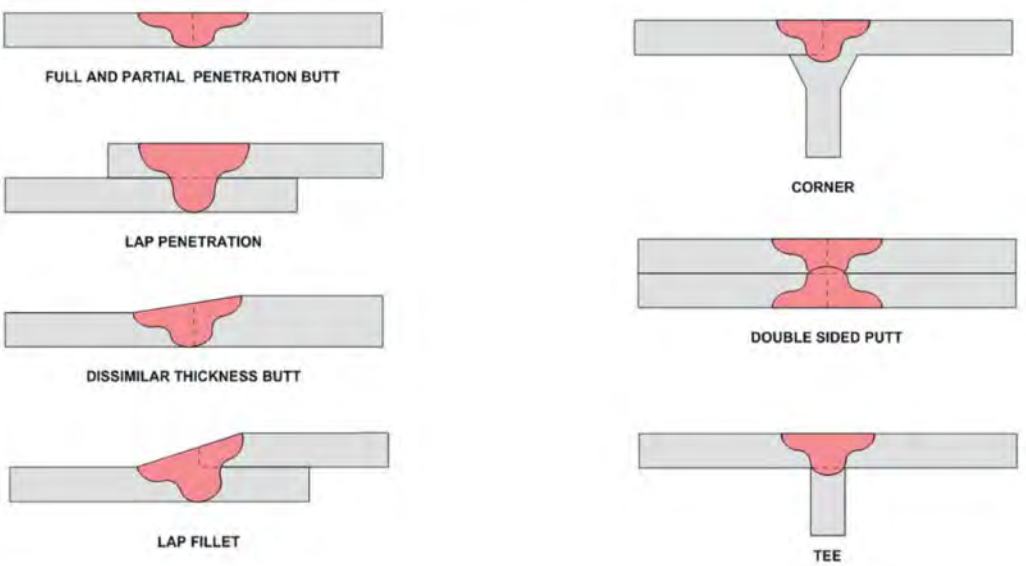
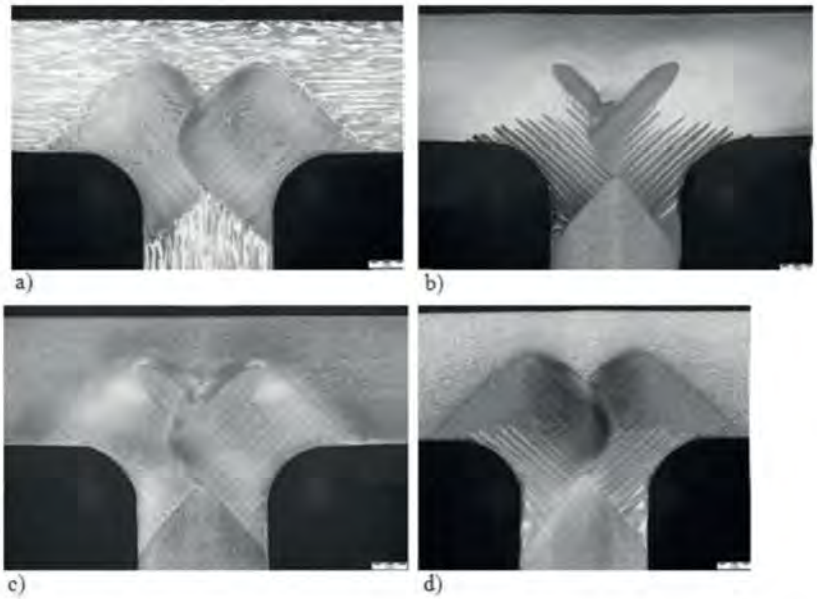


FIG. 4: JOINT GEOMETRIES MOST EASILY ACHIEVED IN FSW

FIG. 5: METALLOGRAPHIC SECTION THROUGH A RADIUSED CORNER FILLET WELD MADE BY TWO FSW PASSES IN 8MM THICK AA6082



The greatest obstacle to transferring the technology of friction stir welding from light metals into steel has been that of finding a tool material with which to stir the steel. Aluminium starts to soften at 300°C and flows sufficiently well for friction stir welding at 450°C. FSW tools made of steel are able to withstand such temperatures and retain adequate strength, and also tend not to react with most types of aluminium with the exception of 7xxx grades.

For welding these higher strength grades, and aluminium thicker than around 40mm, the FSW tools are typically made of nickel cobalt superalloys such as MP159. Steel, however, does not soften and flow sufficiently for friction stir welding until almost twice the temperatures experienced with aluminium, typically around 900 to 1,000°C.

Had it not been for the extremely good mechanical properties observed in the short welds that were able to be made in steel, under laboratory conditions, then the process would probably have remained limited to use in the lower strength, easily plasticised metals. However, the potential to obtain the same benefits in steel as had been seen in aluminium, magnesium and copper acted as significant drivers for further development, and FSW tools are now being introduced into the market that can make industrially useful lengths of weld in steel.

Several tool manufacturers, most recently MegaStir Inc of the US and Element Six in the UK, have developed FSW tools for steel based upon a hybrid materials technology, combining hard wearing and chemically resistant superhard ceramics with a strong, tough, metallic component in order to produce a tool capable of welding industrially useful lengths of steel under industrial rather than laboratory conditions.

Element Six's latest FSW tools for welding 6mm thick steel have been tested at TWI, shown to be consistent from batch to batch, and capable of producing defect free welds in carbon steel under several different testing conditions.

The high strength and elevated temperatures required to friction stir weld steel currently impose thickness limitations on the process. This is due to limitations inherent in the tool materials rather than the FSW process itself: when welding aluminium alloys plates of up to 75mm thickness have been welded in a single square butt pass and up to 160mm has been reported in a two pass weld. The tools currently entering the market for steel are aimed at welding steel from 2 to 6mm in thickness, with a second family of tools under development for thicknesses up to 12mm.

The fine grained microstructure seen in friction stir welds generally provides them with tensile strength properties closer to the parent metal than is typically the case with conventional fusion welding. With steel, this benefit is further enhanced by the fact that welding takes place in the transformation temperature range and careful selection of the welding parameters can exert a useful degree of control over the phase transformations that take place during the welding process. It is possible, for example, to make welds optimised for strength or for toughness, or a combination of both, depending upon the service requirement.

A major benefit of the FSW process is that it produces very little distortion. As the metal being welded does not melt, and thus does not pass through a solid to liquid to solid phase change with its associated volumetric change (up to 4% in the case of some alloys), the distortion induced in the welded fabrication is significantly less than seen with conventional arc or laser welding techniques. The heat input to the weld zone in FSW is far more localised, and generally more rapidly dissipated, and the work pieces rigidly clamped, thus further reducing the potential for distortion.

Dissimilar welds

As FSW is a solid state, (i.e. no melting) welding process, it is far less influenced by the alloy content of the steels being welded. It is therefore possible to weld different grades of steel together more easily than with other techniques, including carbon to Duplex

FIG. 6: METALLOGRAPHIC SECTION THROUGH A WELD MADE BETWEEN 8MM THICK S355 CARBON STEEL AND S32205 DUPLEX STAINLESS STEEL

stainless steels, and to weld steel grades that are found challenging to weld by other processes.

Fig 6 shows a dissimilar metal weld made between S355 carbon steel and S32205 Duplex stainless steel. From the micrograph it can be seen that no alloying has taken place between the two different steel grades, the joint is made purely by mechanical mixing. No alloying elements have been lost from either of the two grades in the weld zone, nor has elemental segregation occurred in this region. The Duplex stainless steel retained the phase balance of the original parent metal, albeit with a much finer grain size in the weld zone.

Samples taken from the weld passed both face and root bend tests, and under tensile testing the sample failed in the parent carbon steel away from the weld area.

Interest has been shown by the shipbuilding industry in the potential of the FSW process to weld metals with very dissimilar plasticisation temperatures, for example joining aluminium to steel. Though this is difficult, with aluminium for example having a melting point considerably below the softening point of steel, aluminium to steel welds have been achieved at TWI. Samples taken from the fabricated plate for tensile testing failed in the parent aluminium rather than the weld, indicating that the weld strength was at least as good as that of the weaker of the two parent plates. Further work would need to be done to investigate the long-term properties, particularly fatigue and corrosion of such dissimilar metal joints, before it was adopted for industrial use.

Project RESURGAM

Given the availability of effective and increasingly reliable tools for steel FSW, TWI established a consortium of companies in the shipbuilding sector to bid for EU funding to identify and investigate potential applications for steel FSW, resulting in the RESURGAM project.

The Robotic Survey, Repair & Agile Manufacture (RESURGAM) project will combine the development of FSW technology for steel with the introduction of digital manufacturing techniques for both the initial modular fabrication of ships across multiple sites and the in water repair of damaged ships or marine structures. RESURGAM's FSW element will look at developing a suite of tools able to weld multiple grades of steel from 2 to 12mm in thickness, in air and under water. These tool developments will be accompanied by the development of a modular FSW system that can be retrofitted to existing CNC milling and machining centres and a robotic system that can be deployed underwater to make in situ repairs.

These fabrication and repair capabilities, backed by the secure, digital Industry 4.0 infrastructure and techniques already in widespread use in the automotive and aerospace industries, will facilitate the rapid, coordinated but distributed modular manufacture of ships and watercraft throughout Europe. Practically, this will allow ships damaged anywhere in the world to have the option of being repaired in place without the need to travel to the nearest drydock.

Conclusions

FSW has a proven history in the marine sector for the fabrication of small to medium-sized aluminium ships. Innovation continues in further developing the process for aluminium fabrication, particularly for corner and fillet welding, but the recent development of tools from several manufacturers that are capable of welding steel now opens up the prospect of applying the process to the fabrication and repair of larger steel ships and potentially offshore structures such as oil production platforms, pipelines and wind turbine towers.

Considerable further work remains to be done to deploy steel FSW industrially:

- technically to develop the tools and welding process;
- with potential users of the process to tailor it to industry's needs;
- and with the classification societies to ensure it meets their acceptance.

Project RESURGAM provides an immediate route forward for the technical development programme, and TWI is already working with classification societies such as Lloyd's Register to address the requirements of the Certification process. The involvement of naval architects, designers and potential users of the process is now sought to ensure that the process meets the needs of industry. ■

Acknowledgments

The RESURGAM project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101007005

PAINTS & COATINGS

BIOFOULING AND SHIP-SPECIFIC FUNCTIONAL SPECIFICATIONS

By **Ralitsa Mihaylova**, Safinah Group

FIG. 1: EXAMPLE OF ANIMAL FOULING ON ARRIVAL AT DRYDOCK. SOURCE: SAFINAH GROUP

The international shipping community is facing several challenges related to environmental performance, with the reduction of greenhouse gas emissions being very high on the international sustainability agenda. One of the issues to address is the presence of excessive biofouling on ships' hulls, which has a considerable adverse impact on ship fuel consumption.

Biofouling is a collective term used for the accumulation of aquatic organisms on surfaces and structures that are immersed in or exposed to the aquatic environment (Fig. 1). The attachment of such organisms on ships' hulls translates into additional fuel costs and hence increased emissions. Heavily fouled pipework, such as engine cooling systems, can also result in operational and safety issues.

Apart from its impact on the ship's operating costs and efficiency, biofouling has been identified as a significant vector for the translocation of non-indigenous marine aquatic species, which could potentially become invasive. To address the risk of introducing potentially harmful species via biofouling, the International Maritime Organisation (IMO) Marine Environment Protection Committee (MEPC) adopted the 2011 Guidelines for the control and management of ships' biofouling to minimise the transfer of invasive aquatic species ('the Guidelines') [1]. In 2018, MEPC 72 agreed to review the Guidelines, which led to the establishment of a Correspondence Group. The review process is currently ongoing with a target completion date likely to be extended to 2023.

To combat biofouling effectively, a suitable fouling control system in conjunction with an adequate risk-based biofouling management strategy is essential. Selecting the optimal system for a specific ship is a complex task as there are multiple options to choose from. These include manufacturers, types of coating technologies, variations in formulations, combinations (or lack) of biocidal packages, together with other ship specific factors.

Coating performance insight

With this in mind, Safinah Group, an independent coating consultancy, has started to release findings based on its unique in-house database of coating condition assessments assembled from supervision activities during drydockings dating back to 2010.

The preliminary findings, based on nearly 270 ships, show that all ships had some level of fouling present on arrival at drydock. The sample includes different ship types (Fig. 2) with deadweights up to 320,000tonnes and an average age of 11.6 years.

Hard macrofouling, comprising calcareous invertebrates, such as barnacles, and also mussels and tubeworms, has been shown to be the most significant contributor to added resistance and therefore additional power and fuel consumption penalties. Across the sample, hard macrofouling covered approximately 273,000m^2, equating to on average more than 1,000m^2 per ship.

Although average biofouling extent is a useful metric it does not account for the variation in coverage across all ships. Analysing fouling patterns by focusing on the frequency of coverage levels provides a more realistic

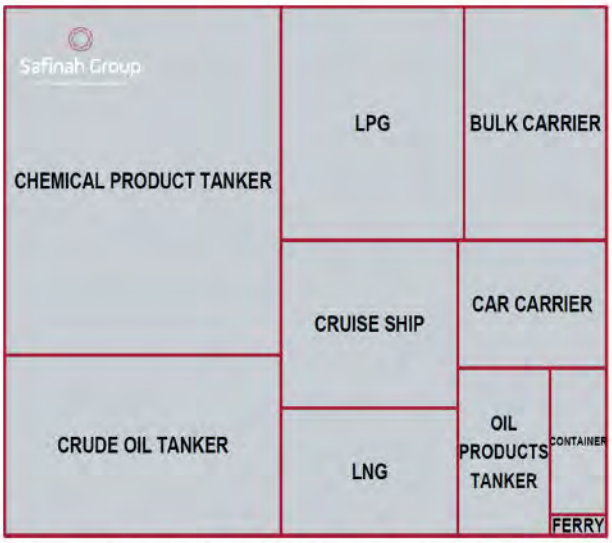


FIG. 2: SAMPLE DEFINITION – PROPORTIONAL SHIP TYPE REPRESENTATION (BY NO. OF SHIPS)

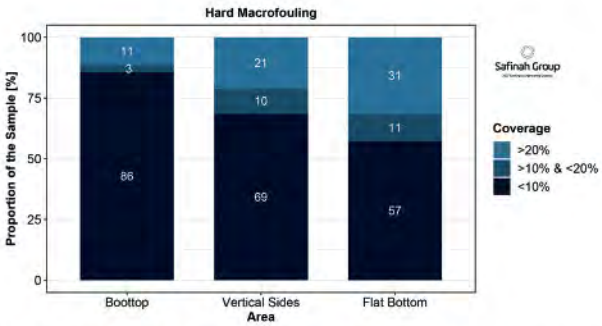


FIG. 3: HARD MACROFOULING COVERAGE AS A PROPORTION OF MAIN AREAS OF UNDERWATER HULL

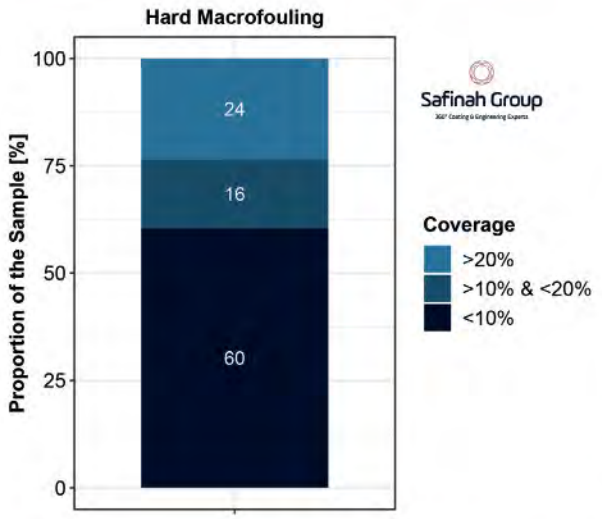


FIG. 4: HARD MACROFOULING COVERAGE AS A PROPORTION OF THE TOTAL UNDERWATER AREA

representation of typical underwater hull conditions. Figs. 3 and 4 show the proportion of observations based on hard macrofouling coverage – namely: (1) less than 10%; (2) 10-20%; and, (3) more than 20%.

Animal fouling (hard and soft macrofouling) is frequently the predominant type found on flat bottoms as many of the organisms are not fully dependent on the availability of sunlight. The data shows that more than 40% of the ships were found to have in excess of 20% hard macrofouling on their flat bottoms (Fig. 3). This effect is a function of the choice of coating, ship type, operational profile (speed, activity and geographic area of operation) and maintenance practices amongst other factors.

According to the sample, 60% of the ships were reported to have less than 10% of their underwater hulls covered in hard macrofouling (Fig. 4), however, this can still result in significant fuel penalties depending on the biofouling composition and dispersal across the hull. Recent research [2] found that 10% coverage by relatively small barnacles (2.5mm diameter and 1.25mm height) can lead to a 27% increase in frictional resistance and hence a 17.5% increase in effective power for a 230m containership with a design speed of 24knots.

In addition to the results shown in Fig. 4, it is worth noting that approximately 10% of the whole sample had in excess of 40% of their underwater areas covered in hard macrofouling. This is a significant amount of biofouling which has a dramatic impact on hull efficiency, resulting in added fuel costs and emissions. It also indicates that proactive biofouling management practices may be less regular as ships approach a planned drydocking. However, the accumulation of 40% of hard macrofouling is likely to result from periods of inactivity or extended periods of low activity.

These results also raise the question of whether the selected coating technologies were suitable for the specific ships in question, and whether this was a result of a poor specification and selection process. Optimal in-service performance is achieved by matching the ship with the most suitable fouling control coating product. Selecting the optimal product must be made taking careful consideration of a multitude of factors such as, but not limited to: operational profiles, activity, speed, environmental factors, and maintenance regimes. This is not just simply a process of opting for a product marketed as 'high performance'. Fouling control products' perceived technology level, which is often a function of marketing literature and product positioning, should not be treated as an objective indicator of in-service performance.

One significant point is that amongst low activity ships, a higher proportion of ships with technologies perceived as 'medium' level had more than 20% of their underwater areas covered in hard macrofouling compared to ships with 'low' level technologies.

The results reported above do not distinguish between the actual operational profiles and the environmental conditions that the ships experienced. However, they can be treated as an indication that product selection should not be based on 'marketed' technology level alone and that there is no one technology that would offer the same level of performance across the fleet. This fact is recognised by the international community tackling biofouling related issues, in terms of emissions and the translocation of invasive species, as evidenced by the efforts towards encouraging the shipping industry to adopt a ship specific approach towards the selection of fouling control products.

Coating Selection Trends

In March 2020, a leading marine insurer claimed that only 30-40% of ships engaged in international voyages are coated with 'high quality' fouling control coatings. According to a sample of Safinah Group's data, the proportion is actually higher – about 70% of ships had products perceived as 'high' technology level applied on the vertical sides at the last drydocking, as opposed to 43% at the previous coating application. This seems to indicate a more significant move towards 'high quality' products. However, it should be noted that Safinah Group's data sample includes a large proportion of ships representing the fleets of owners and operators who have pledged resources and effort to promoting sustainable shipping practices.

Fig. 5 shows technology level transitions at drydocking. Fig. 6 highlights the proportion of ships in the sample with different technology levels applied at the latest drydocking by main underwater area. The selection trends and the proportion of mixed schemes vary significantly across ship types, activity, owner and manufacturer profiles. It

is not surprising that the numbers corresponding to flat bottom and boottop areas are generally lower, however, the tendency to opt for 'high' technology level products is consistent (Fig. 6). It is worth noting that coatings perceived as 'high' technology level are preferred by owners of high activity ships although the ships are slightly older on average.

It was found that a large proportion of the ships with less than 10% hard macrofouling on arrival at drydock switched manufacturers (Fig. 7). A significant proportion of these ships left drydock with a fouling control coating on their hulls perceived as offering superior fouling performance (higher technology level). A potential explanation for this behaviour may be a recent change in ownership. It is also interesting to note that over half of the ships with more than 20% hard macrofouling on arrival left drydock with coating by the same manufacturer, which could imply an existing commercial arrangement or a potentially long-standing relationship. It is also an indication that few owners carry out robust or adequately detailed annual fleet-wide reviews based on ship-specific performance to inform long-term strategy.

Summary

Choosing a fouling control coating product or system is often based on cost, perceptions of quality, performance, and novelty factors. Manufacturing and supply of fouling control coatings is a very competitive industry and aggressive sales strategies are not uncommon.

As a result, fleet discounts and group deals are often one of the driving factors in the selection process. However, such influences may distract from selecting a solution that provides adequate protection for individual ships. For the optimal solution to be identified, careful consideration needs to be given to a variety of ship-specific factors affecting the suitability of potential technologies. Examples of such factors include typical operational profiles and associated environmental parameters, expected activity and speed patterns, refit/newbuild locations, season and product availability, biofouling management options, cleaning equipment availability at typical destinations, and others. The output of such a methodical analysis of various factors is a robust and objective 'functional' specification, as opposed to the 'generic' specifications that dominate coating selection at present.

Choosing a suitable product is an essential element in the establishment of an effective biofouling control strategy, which directly benefits both shipowners and charterers in terms of operational costs, while also limiting the potential carbon footprint of ships and the risk of translocating non-native aquatic species.

Other elements, which should also be considered in order to improve the chances of products achieving expected in-service performance, include surface preparation, coating application, and adequate in-service management and maintenance. Informed choices and a considered biofouling control strategy, which takes into account all critical elements, can only benefit the shipping industry and the environment. Hence, informed independent expert advice, rather than simply reliance on industry guides, is crucial in the development of robust biofouling management practices and ship-specific solutions to achieve optimal hull performance.

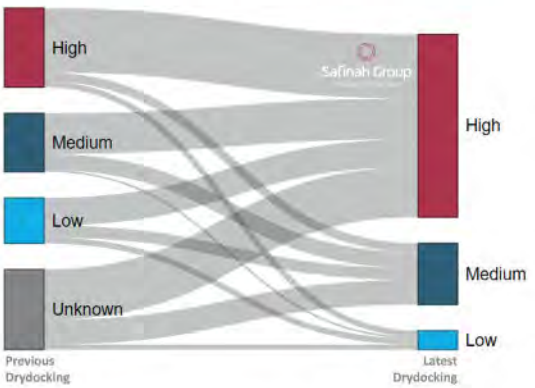


FIG. 5: TECHNOLOGY LEVEL TRANSITIONS

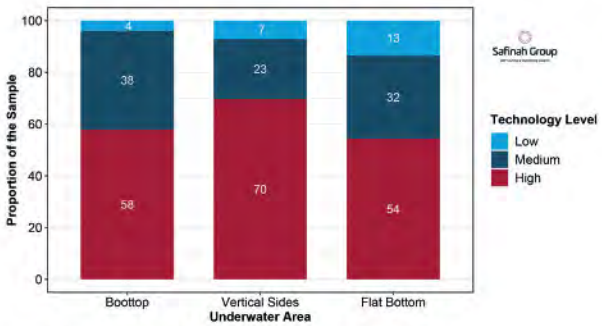


FIG. 6: SELECTION TRENDS (LATEST DRYDOCKING)

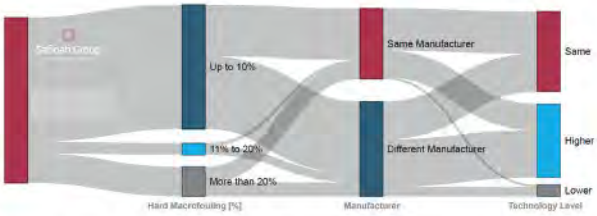


FIG. 7: SELECTION TRENDS BASED ON OBSERVED HARD MACROFOULING

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SAFETY

FROM SAFETY EVENT REPORTING TOWARDS IMPACT ON DESIGN: HUMAN RISK-INFORMED DESIGN (HURID)

The EU-funded project SAFEMODE shows that a deeper knowledge and integration of Human Factors play a major role in evaluating overall risk related to ship design and operation

By **Dr. Maria Carrera Arce**, World Maritime University, **Andrea Lommi**, CETENA, and **Beatriz Navas de Maya**, University of Strathclyde

Nowadays, the maritime world is still strongly linked to traditional and widely adopted rules (regarding systems design, usability, maintainability, habitability, etc.), most of which are standardised in existing regulations. Even if this situation makes it easier to develop, integrate and operate a system in a new ship, it may lead the designer to overlook the role of Human Factors (HF), which should be taken into consideration at a much deeper level.

More specifically, ships' systems are normally designed for a nominal condition where redundancy allows a certain degree of degraded performance, in which case the system's residual operability still allows it to conduct navigation at a satisfactory safety level (e.g., 'Safe Return to Port'). This principle is correct, but mainly focuses on system operability and expected operator actions, while little attention is given to the degraded performance of humans, and consequences of factors such as sleep deprivation, fatigue, unreliable communication, and excessive workload among others. All these factors could further degrade ship operability and should play a role in overall risk assessment.

Similar tradition-related issues are present not only in the shipbuilding sector but also affect other closely related fields such as incident investigation and analysis and, mostly, the actual operation of a ship. The co-presence of multiple risk factors could generate unpredicted results and may lead to accidents where even understanding the contributing factors could be difficult.

Therefore, even if the increase in automation level and the adoption of more sophisticated systems have helped to reduce accidents due to systems failure, the human component of accidents is still prominent and possibly less predictable than it was in the past. Moreover, it is evidenced that increased automation and new technologies change human work, transform human-machine interfaces (HMI) and create opportunities for more and "novel "risks, including risks that are, as of yet, unidentified. Starting from these considerations, the purpose of this article is to document the HF integration process defined in the SAFEMODE Project and its use in the framework of risk assessment, showing that a deeper knowledge of HF aspects can play a major role in evaluating overall risk related to ship design and operation.

SAFEMODE Context

The SAFEMODE Project uses data from casualties and near miss reporting to assist designers and other end users involved in systems and operations design. One of the challenges of learning accurately from reporting and integrating HF into risk designs comes from the scarcity of HF data from safety events. The other significant challenge involves the quasi-absence of effective learning loops from operators to designers back to operators.

The final output of SAFEMODE is the novel Human Risk Informed Design (HURID), which integrates HF into design processes no matter the maturity of the design project being considered. It then serves as a guide for applying HF in maritime and aviation case studies. HURID offers tools and data for designers and risk assessors, enabling them to take HF risk-based considerations when designing transport systems and operations.

The HURID framework follows a multi-step process, which includes four major components to assist the designer (Fig.1): the SHIELD database, the HF taxonomy, the Human Factors Toolkit, and the Risk Models for collision and grounding. These elements can be used individually or combined to develop a risk-informed design that addresses the relevant HF involvements and impacts of a new design.

HURID helps the designer navigate through the various HF approaches and techniques to see which ones are best suited to the design project. Along with designers/ developers other main categories of HURID end-users include HF practitioners, safety experts, inspectors/ surveyors and auditors, investigators, and HF novices; consequently, HURID is designed to be scalable,

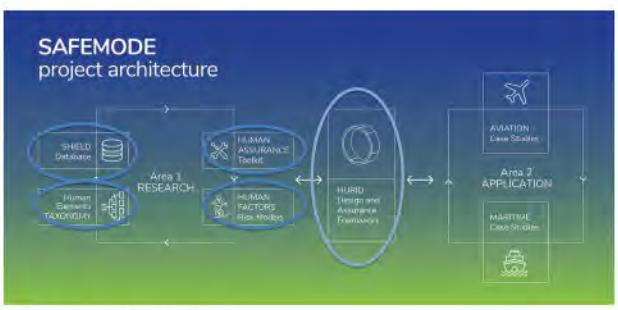

FIG. 1: HURID COMPONENTS

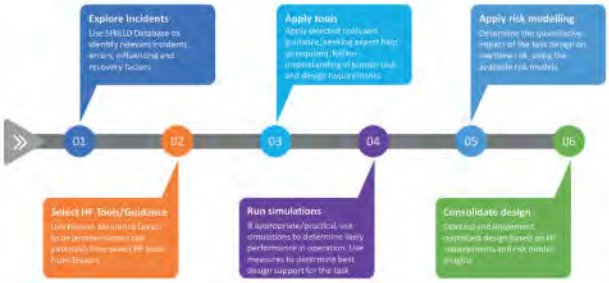

FIG. 2. STANDARDISED HURID APPLICATION PROCESS

proportionate to the risks involved, and customisable to user needs.

HURID Process

The standardised HURID application process is meant as a way to guide the end-user through phases whose logical scheduling maximises the potential of HURID components, especially considering the matching between the outputs of each stage with the needed inputs of the next one. Phases closely correspond to those usually followed in conventional HF-compliant design, but make use of HURID unique components to boost their efficacy and depth. The application process is depicted in Fig. 2.

The HURID process considers simulation as the main element for design validation, but validation of other kinds of activities can be used according to the nature of the design. For instance, role-play validation can also be carried out, especially for procedures design, which is impossible to validate through simulation. Moreover, the HURID process can be adapted to iterative validation processes by repeating steps 4, 5 and 6, and then helping to consolidate early prototypes into more refined systems.

Case Studies

The applications of the HURID Framework to the maritime domain is being demonstrated through specific domain case studies, which allow the evaluation of all HURID components. This is taking place in agreement with the aviation domain in order to maintain a cross-domain approach. Two maritime examples among those considered in SAFEMODE are the "Operator Assessment of Remote-controlled Ships" (CS1) and the "Simulator-based evaluation of human response in emergencies for ship collision" (CS2).

In the first case study (CS1), SAFEMODE addresses the Maritime Autonomous Surface Ship (MASS) concept by validating and improving an existing HMI through HURID application.

Following the HURID process reported in Fig. 2, Phase 1 was carried out by selecting relevant incident reports and analysing them to identify the main issues to be addressed by the subsequent steps. Moreover, Phase 2 led to the selection of the most relevant HF tools, namely Task Analysis techniques and Human HAZOP method, which are both very effective in the evaluation of new systems from the perspective of operators. Output material from methods application (Phase 3) can be gathered during interviews where system designers and experienced professionals provide contributions following a structured protocol. The strength of this approach is that it enhances communication and sharing of ideas, overcoming organisational barriers and leading to a common understanding of needs and design constraints, formalised in a list of HF-related requirements.

Such requirements are one of the main inputs to be followed by the system designer to update and improve the existing HMI in preparation for Phase 4, i.e. the validation of the new design in comparison to the old one through simulation-based experiments with human-in-the-loop.

Results from Phase 4 will be the starting point for the validation of barrier-based risk models, leading to a better understanding of the operation and enabling the quantification of risk corresponding to different usage scenarios (Phases 5, 6). This outcome is particularly relevant considering the actual application (MASS concept), in which a tool for risk evaluation could effectively enable MASS class certification and insurance.

In the second case study (CS2), SAFEMODE deals with collision events during navigation. As a starting point, three incident reports were used to identify the typical factors leading to collisions. The chosen safety-relevant events included: (a) deviation from navigation procedures, (b) navigational equipment breakdown, and (c) main engine failure, as the main reasons for the accidents (Phase 1).

For each of the three situations, assessment activities were carried out by applying HURID methods (Phase 2-3). First, a Task Analysis was developed to detail the actions performed by the bridge team in order to fulfil its duties. Tasks were also arranged in the form of three Operational Sequence Diagrams (OSD). The OSD can effectively help the designer point out where the actual actions deviated from the correct (nominal) sequence. Finally, the Critical Incident Technique was applied to further detail the reasons behind the erroneous actions that led to the accidents, enabling focused interventions on each role and at the correct level (e.g., safety culture, training, language-related barriers, procedures, automation, etc.).

The outcomes of this phase helped identify the following main points onto which acting for reducing the risk related to collision avoidance (Phase 4):

- **Human Factors-related interventions**
  Most of the identified problems are related to inadequate safety culture (leading to double duties for key personnel, lack of sleep, etc.) and inappropriate training of crew. Communication issues were also highlighted, due to cultural barriers or insufficient/inefficient verbalisation. The design session in respect of these aspects has identified that effective communication is one way to enhance safe navigation of the ship, and a 'think aloud' guideline is currently being analysed to implement such ideas into practical bridge operation. This concept is also inspired by the aviation sector, where the 'read-back' concept is common, and communication between pilot and co-pilot is continuous and well structured.

- **Decision support systems**
  The need for better navigation-related automation

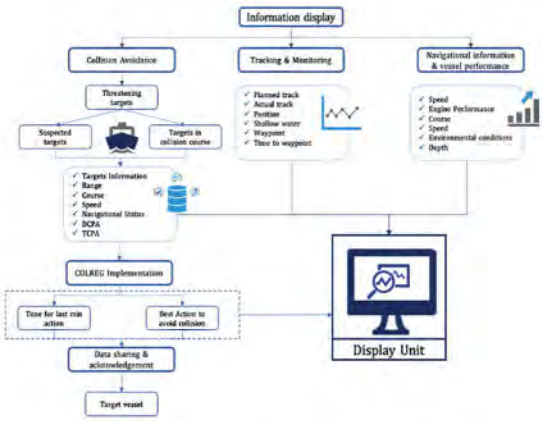

FIG. 3. CS2-INTEGRATED DECISION SYSTEM FRAMEWORK

systems was also pointed out, particularly due to the limited ability of current systems to provide accurate predictions of possible collisions in relation to the external environment. To address this problem, an Integrated Decision System has been proposed (Fig. 3). The system is able to continuously monitor the external picture giving suggestions on course and speed informed by long-term collision predictions. Such a system could help fill in the current gaps, improving the bridge team decision-making process.

In all cases, the solutions that HURID helped to identify are intended as an aid to the bridge team in improving a degraded performance arising from multiple and systemic reasons, typically related to fatigue, excessive workload, co-working issues among others.

SAFEMODE Risk Modelling

In this framework, two risk models have been developed for collision and grounding accidents in relation to various operational environments (open sea, congested or narrow waters). Such risk models are refined and validated thanks to the above mentioned case studies.

The development of the risk models in the context of SAFEMODE follows six steps (Fig. 4):

The first step refers to the determination of the risk model scope, followed by definition of the accident type, the operational environment/services and the systems/ elements involved.

FIG. 4: THE SIX STEPS OF THE RISK MODELS DEVELOPMENT PROCESS

The second step involves the development of the backbone, the fundamental pillar of the risk model structure, consisting of precursors, barriers, and circumstantial factors, whose identification is based on incident/accident reports, existing risk models (from the international literature or developed in previous research projects), and input from aviation and maritime experts in the consortium. An example of the backbone for the "Collision in the Open Sea" risk model is depicted in Fig. 5.

The third step refers to the development of the detailed risk model, i.e. the identification of contributors (causal factors) to the failure of barriers and induced events. The contributors were modelled by implementing Fault Tree Analysis (FTA). Following this top-down approach, the basic events (failures) that may lead to the failure of the top event (barriers or induced events of the backbone) were identified.

The fourth step addresses the human contribution to the risk model by means of the human influence layer, based on the SAFEMODE HF taxonomy and containing several additional performance-shaping factors, linked to basic events of the developed risk models and providing essential information concerning the contributory conditions leading to human failure. Furthermore, the basic events that refer to human actions were compared to the Generic Task Types in the Human Error Assessment and Reduction Technique (HEART).

The fifth step addresses the quantification of the risk models. During this process, the various elements (precursors, barriers, circumstantial factors, contributors, and performance-shaping factors) were quantified using the following data: a) accident/incident reports from the SHIELD database; b) operational data (e.g., equipment logs, etc.); c) data derived from the respective case studies; and d) expert judgement in case no data are available.

Lastly, the final step includes the validation process for Steps 2, 3 and 4 of the model. It is performed either by employing a new dataset of accident/incident reports (not previously used as input to the process), or by incorporating experts that were not involved in the development of the steps. Based on the validation process, the structure of the initial backbone (Step 2), detailed risk model (Step 3) and human influence layer (Step 4) are modified accordingly.

The first case study (related to the MASS concept) will allow the risk models to be refined, determine the robustness of the barriers and identify critical elements, possibly pointing out any additional risks introduced by the use of remotely operated ships. The risk models can be used at different stages of a new concept development:

- At risk model refinement level: due to the unavailability of MASS incident reports, key HF identified in accidents with manned ships (e.g., coping with emergency situations, inefficient operation of the vessel, insufficient interaction with VTS, etc.) and related failed barriers will be transferred to the MASS concept in order to take advantage of existing knowledge.
- At concept definition level, to support the identification of weaknesses and need for

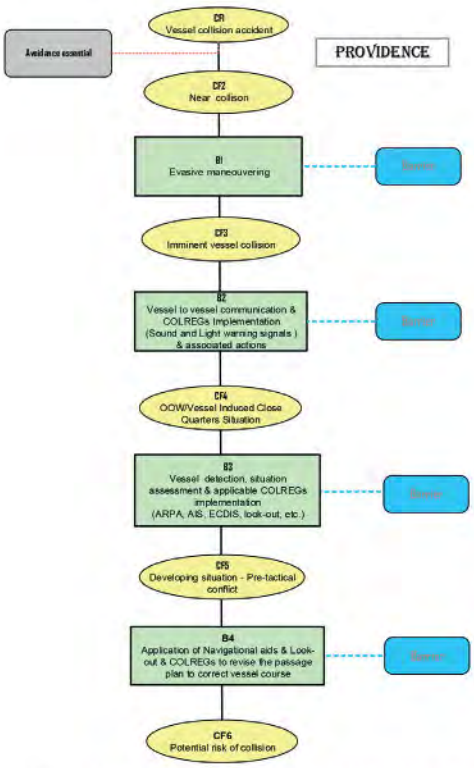

FIG. 5: OVERALL BACKBONE STRUCTURE OF THE "COLLISION IN OPEN SEA" RISK MODEL

enhancement of risk control options, or if a solution is already identified, assess the expected benefits of implementing this solution in remotely operated ship navigation. In this case study, it is expected to improve the barriers linked to navigation conflict detection and collision avoidance.

- At concept design level, to identify the HF that can be improved and focus on new system functionalities aimed at enhancing safety. Moreover, the contribution of the HF to risk can be evaluated, and risk control options can be identified. For example, loss of concentration might be caused by task overload and fatigue. The design of a new HMI that integrates relevant information without overwhelming remote operators may have a significant impact on the navigation of remotely operated ships.
- At concept validation level, to evaluate the effectiveness of the new design by comparing the risk level without (baseline) and with the implementation of the new concept (HURID). Additionally, the success of the barriers put in place can also be evaluated. Examination of barriers will also suggest ways to build exercises, creating the conditions for barrier failure.

The second case study aims to analyse and improve human response in emergencies (such as ship collision, grounding, engine failure, etc.) by proposing improvements to onboard procedures and/or the implementation of new decision support systems. The risk model can be used:

- At risk model refinement level, to identify key contributors to the failure of barriers and risk control options. Additionally, a deeper analysis of ship accident causes will support the study of human response and allow the identification of alternatives to improve the effectiveness of barriers and enhance human performance.
- At concept definition level, to support the identification of flaws in the barriers and risk control, and also to support the identification of new solutions to improve human performance and enhance navigation safety. Additionally, errors by the bridge team caused by factors such as fatigue, stress, loss of concentration, workload, etc. will be assessed with the support of risk models.
- At concept design level, to identify which HF can be improved and focus on new procedures and designs aiming at improving human performance, helping to identify risk control options. Furthermore, the risk model can be used to estimate the overall risk deriving from the implementation of new procedures.
- At concept validation level, to assess the efficiency of new procedures by comparing the risk level without (baseline) and with the new concept. Starting from the planning phase, barriers related to VTS and pilot management, COLREG implementation, communication, etc. will be identified. Then, during validation activities, human error contribution to each barrier (failure or success) will be measured and analysed.

Human and Reasoned Approach

The SAFEMODE project shows how to effectively and systematically apply a modern and reasoned approach on Human Factors integration to design and incident evaluation processes, with a particular focus on the quantification of risk.

Refined risk models developed by SAFEMODE can be effectively employed to identify issues that may currently be unpredictable with a non-risk based driven approach. Moreover, these risk models can be used for revising existing designs and procedures immediately understanding the HF components to be improved and the consequences of "human error".

For these reasons, risk-based Human Factors integration can be regarded as one of the main enabling processes for the implementation of modern technologies (e.g. MASS) into real products, effectively leading to a convergence between designers, HF professionals, classification societies and insurance companies on a common ground. ■

For further information visit: https://safemodeproject.eu/

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CALENDAR

What's happening next?
For more information please visit: **www.rina.org.uk/RINA_Events**

SEPTEMBER, 2021
WIND PROPULSION 2021
RINA/IWSA conference
London, UK

OCTOBER 20-22, 2021
CONTRACT MANAGEMENT
RINA conference
London, UK

NOVEMBER 10-11, 2021
PROTECTING MARINE ENVIRONMENT THROUGH DESIGN, CONSTRUCTION AND OPERATION
RINA conference
London, UK

NOVEMBER, 2021
GREEN SHIPPING
WEGEMT/RINA course
Online

DECEMBER 1-2, 2021
WATERJET PROPULSION 2021
RINA conference
Onilne

JUNE 28 - JULY 2, 2021
IMO COUNCIL
International forum
Online

JUNE 28 - JULY 2, 2021
KOREA ONLINE MARITIME TRADE SHOW (KOMTS)
International conference
Online

AUGUST 26-27, 2021
OFFSHORE RENEWABLE ENERGY (CORE)
International conference
Online

AUGUST 31 - SEPTEMBER 2, 2021
HIGH SPEED BOAT OPERATIONS (HSBO)
International Forum
Gothenburg, Sweden

SEPTEMBER 20-24, 2021
TECHNICAL CO-OPERATION COMMITTEE
IMO International forum
Location TBC

SEPTEMBER 21-24, 2021
NEVA
International conference/exhibition
St Petersburg,
Russia

OCTOBER 4-8, 2021
MARITIME SAFETY COMMITTEE (MSC)
IMO International forum
Location TBC

OCTOBER 18-22, 2021
INTERSESSIONAL WORKING GROUP ON THE REDUCTION OF GHG EMISSIONS
IMO International forum
Location TBC

OCTOBER 21-22, 2021
SMART & GREEN TECHNOLOGY FOR SHIPPING AND MARITIME INDUSTRIES (SMATECH)
International conference
Online

NOVEMBER 8-12, 2021
MARINE ENVIRONMENT PROTECTION COMMITTEE (MEPC)
IMO International forum
Location TBC

NOVEMBER 19-20, 2021
ICSOT INDONESIA
International Conference
East Java, Indonesia

NOVEMBER 24-26, 2021
IMO COUNCIL
IMO International forum
Location TBC

NOVEMBER 24-26, 2021
SAFETY, RELIABILITY OF SHIPS, OFFSHORE & SUBSEA STRUCTURES (SAROSS)
International conference
Glasgow, UK

JANUARY 10-13, 2022
NOR-SHIPPING
International exhibition
Lillestrøm, Norway

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