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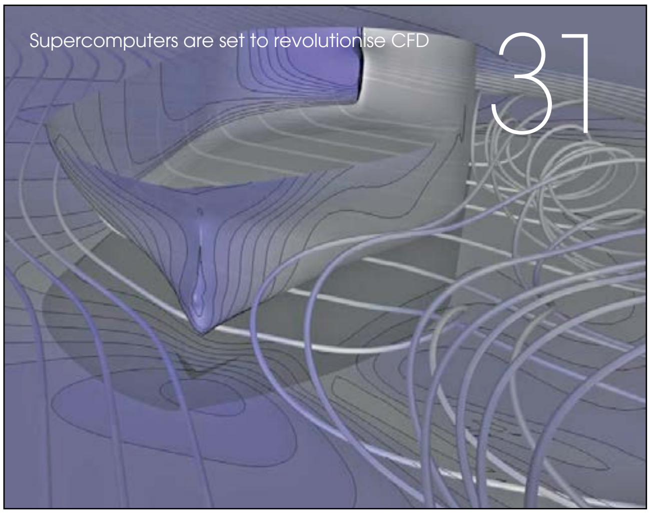

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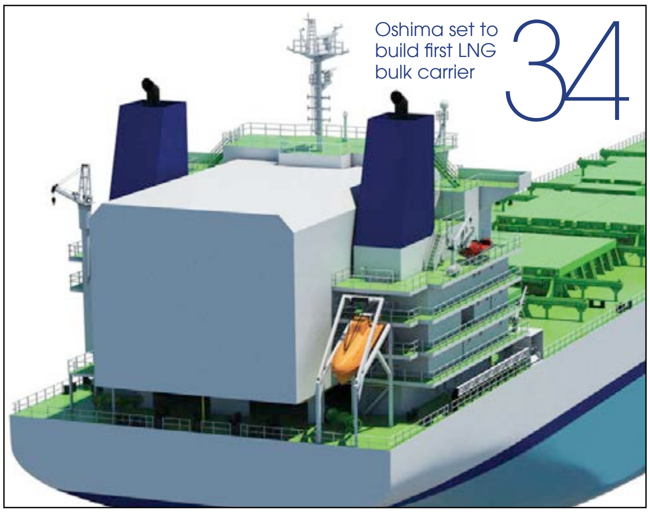

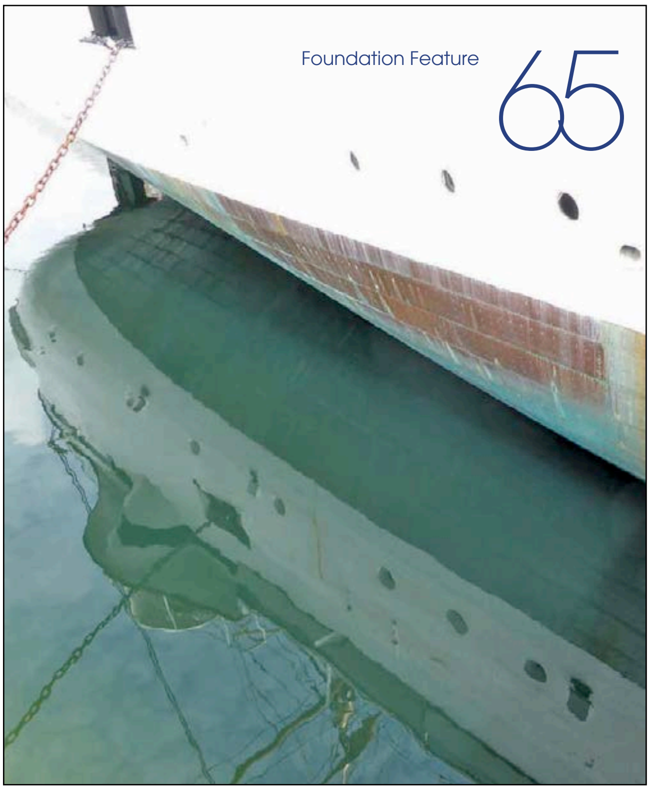

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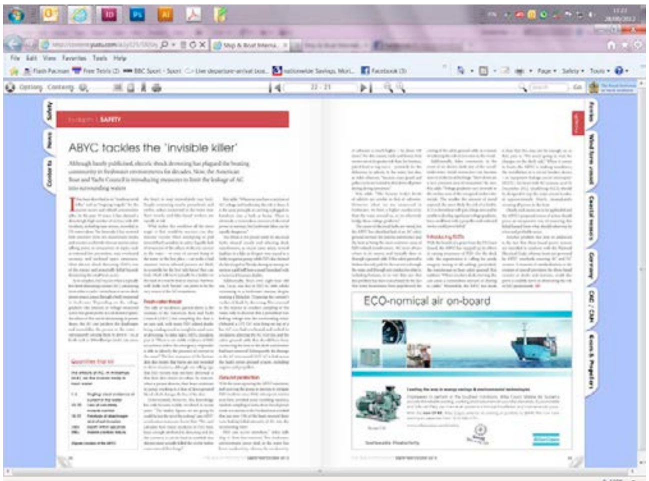

Changing times

Designs are improving with the development of CFD and super computers

According to Bob Dylan "those not busy being born are busy dying:" and while both the outgoing and incoming Secretary General at the IMO remain very much alive, as does the maritime industry, the sentiment in the lyric reflects the continuing evolution of both the IMO and the industry.

Last month Ki-tack Lim, a Korean by birth was elected to the position of Secretary General at the IMO. Lim will succeed Japan's Koji Sekimizu whose four year stint will end in December.

Asked if he could outline his most pressing policy aims, Lim told *The Naval Architect*: "I need to go through a fine tuning process with respect to specific contents of policies for the future based on consultation with the current SG [Secretary General] and key senior staff from the IMO."

The pace of technological change is expected to increase with the ever greater pressures being applied to shipowners, operators and regulators to improve the environmental performance of the industry.

Lim will lead the charge towards a greener industry from next January and that will not see a raft of new regulations, but rather a move to make certain that existing rules are enforced. In addition he believes that the IMO must been seen as the sole authority governing the shipping industry. This is a challenge in itself as the EU and US authorities seek to push the IMO into regulation through the promotion of unilateral regional laws.

Perhaps the first time this was evident was 25 years ago when the US Government introduced the Oil Pollution Act 1990, known as OPA 90, following the grounding of *Exxon Valdez* in Prince William Sound. Following this accident, authorities in the US required all crude oil tankers entering US waters to be double hulled, a norm which is now enshrined in IMO rules.

Further examples of regional authorities driving IMO policy have followed since, particularly in the environmental field as the EU and US have both introduced Emission Control Areas again driving the industry to be cleaner with the IMO lagging. While regional authorities are not exactly "dancing beneath the diamond sky with one arm waving free," to coin another Dylan phrase, Lim will have his work cut out if his aim is unify the 170 plus nations and various vested interests into an authority that can keep pace with the increasingly dynamic world which it seeks to regulate.

It is in the environmental sphere where the IMO's position and Lim's policy will most likely be tested to the limit. In an area of regulation which has seen the Ballast Water Convention stalled for more than 10 years and emission controls that were introduced in 2013, some 16 years after Kyoto, the judgement on IMO would have to be 'must do better'.

However, the industry is moving forward with better designs and this is being aided by the development of new computational fluid dynamics (CFD) techniques and the inexorable rise in computing power.

In part this is being driven by competition between nations. South Korean yards, so heavily in debt with a number on the point of collapse, have seen the global economic crisis put an effective brake on new orders and the emergence of China as tough competition to its neighbour's pre-eminence in the shipbuilding field has led to the Koreans looking for ways to stay ahead of the competition. One way by which naval architects have managed to stay ahead is through the development of CFD as a design tool.

In some circles it is believed that the improvement in CFD could lead to the complete demise of towing tanks. Though this is not immediately on the cards it is probable that there will be a reduced need for model testing in expensive tanks and then engaging in the imprecise scaling up of results to try and determine how a vessel design will work.

Indeed the scaling up process is so dogged with difficulties that one yard, Japan's Tsuneishi, has built a one tenth size, 23m, model at a cost of US$1 million in an attempt to reduce the scaling issues (see April *The Naval Architect* pages 18-19).

Development of CFD in shipping has, however, been slow compared to other industries, such as the motor manufacturers and aircraft builders who have embraced CFD, apparently, more readily. Even so the pace of change is certainly gathering in the shipping industry with both technology developing rapidly and political and economic pressure forcing changes. For Lim, Dylan holds out the hope that just because the industry started more slowly than some others, the race is not over until you cross the line when he says "the first one now will later be last, for the times they are a-changin'". *NA*

IMO

Ki-tack Lim elected

The current president of Busan Port Authority, Ki-tack Lim has been elected to the position of Secretary General of the IMO and will be officially appointed to his new position in January next year.

Industry safety will remain at the core of IMO work says Lim and the regulations that are available must be enforced. "The challenge for IMO is not a lack of regulations, but how best to apply and implement the existing requirements." This will be a major focus of his tenure as Secretary General. He will also look at "streamlining" the regulatory process.

To achieve those aims Lim intends to focus on strengthening the role of flag states, harmonise port state control activities and create a strong safety culture within the staff group in the industry and also to improve the safety of ships in coastal areas and at the "Ship Port Interface".

Marine Equipment

German suppliers boost sales

Marine equipment suppliers in Germany increased their sales over the last year by 1.7% to €11.9 billion (US$13.13 billion) said the German Engineering Federation (VDMA).

However, the outlook for the next three to five years is for a tough period with the levels of new orders falling.

The figures show that 74% of equipment orders were for export and the increase was achieved in a market that is seeing the increase of vessel orders slow and a significant decline in orders for the offshore industry, said Dr. Alexander Nürnberg, chairman of Marine Equipment and Systems at the VDMA.

VDMA executive board member Martin Johannsmann told The Naval Architect that while Clarksons is forecasting new orders of 1,300 ships for the coming year, "we believe it is less than 1,000, it will be tough," he admitted.

Johannsmann said: "The sector knows this cyclical pattern, the ups and downs with incoming orders, changing capacity utilisation in production and fluctuations in market prices; we see this development as a chance to expand our leading role on the competitive global stage. We're investing now to offset the volatility of the markets. An increase in productivity and flexibility, with new approaches such as Industry 4.0, are the required results."

The VDMA believes that German equipment suppliers "must not be arrogant", even if they have performed strongly. "Chinese yards have a preference for local manufacturers and they are learning fast [in terms of quality]".

He added that the investment in the offshore business would not return for at least a year even after the oil price recovered to US$100/barrel. He said that investors would wait to see if the price rise would remain relatively stable.

It is up to equipment suppliers to maintain the technological development that can drive the industry forward with new solutions for environmental protection.

Scrapping

Bulk scrapping gathers pace

Scrapping of bulk carriers between 1 January this year and 30 June has picked up with China scrapping the most ships, but Greece scrapping the biggest.

New orders for Capesize vessels as seen in Clarksons statistics (The Naval Architect February 2015 pages 34-35) after three years of decline, with 161 Capesize vessels expected to be delivered this year and another 171 next year.

Greece	Number	Total DWT	Average Age
CAPESIZE	20	3,227,000	19.9
HANDY BC	13	397,200	29.2
PANAMAX BC	16	1,139,800	27.8
HANDYMAX BC	5	220,500	27.4
Total	**54**	**4,984,500**	**23.4**
China	**Number**	**Total DWT**	**Average Age**
CAPESIZE	7	1,093,600	19.8
HANDY BC	29	887,700	22
HANDYMAX BC	17	746,700	28.4
PANAMAX BC	17	1,199,700	22.6
POST PANAMAX BC (Coal Carrier)	1	97,800	23.9
Total	**71**	**4,025,500**	**24.2**
Singapore	**Number**	**Total DWT**	**Average Age**
CAPESIZE	7	1,299,000	24.3
HANDY BC	3	85,500	30.5
PANAMAX BC	1	75,500	20.8
Total	**11**	**1,460,000**	**23.7**

In all 136 bulk carriers have been scrapped this year with the average age of the Capesizes coming from Greece and China below 20 years old compared to the handy and Panamax sizes which have average ages above 25 years old from Greece and mainly 24 years old from China. Only the Panamaxes from Singapore come close to the Capesizes at 20.8, but this is only one vessel.

Engines

AIP for gas turbine ship

Hyundai Heavy Industries (HHI) says it has jointly developed the world's first gas turbine-powered 174,000 m3 LNG carrier with GE Aviation and Marine (GE).

UK class society Lloyd's Register has given the design its Approval In Principle certificate.

GE's gas turbine-based Combined Gas turbine Electric and Steam system (COGES 2.0) are IMO Tier III-compliant and the vessel is "expected to save shipowners or operators an estimated US$17.83 million on the assump-

tion that the LNG carrier operates for 20 years with an annual operating cost of US$720,000, since it does not need additional equipment to handle exhaust emissions," says the yard.

Operating and maintenance costs for the gas turbine are expected to be lower as the engine is 60% lighter than conventional units.

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Classification

New rules for DNV GL

Norwegian and German class society DNV GL has sent its new unified rules to 800 customers as part of what it calls "an extensive external hearing process before their publication and entry into force".

Class rules define the organisation and DNV GL has operated with two sets of rules since the merger of the two companies DNV and Germanischer Lloyd in September 2013. The new unified rules are expected to be introduced January 2016.

"From the beginning of this project, we wanted these rules to be unique in the way they reflected industry experience and input. So our objective has been to have our customers and stakeholders deeply involved throughout the development and implementation process. Already, at the recent Nor-Shipping trade fair we signed several joint development projects with leading yards to work together with us to ensure the rules deliver the quality, safety and process efficiency our customers expect," says the COO of DNV GL – Maritime, Knut Ørbeck-Nilssen, who will take on the role of CEO in August.

Knut Ørbeck-Nilssen, COO of DNV GL - Maritime and he will take on his role of CEO in August

Autonomous ships

Robo-ship a step closer

Finnish technology and innovation funding agency Tekes is funding a €6.6 million (US$7.29 million) project into the development of autonomous ships.

The Advanced Autonomous Waterborne Applications Initiative will be led by Rolls-Royce and will include partners from academia, the classification societies and industry who will work to produce the preliminary designs for the next generation of technologically advanced ships.

"The project will run until the end of 2017 and will pave the way for solutions - designed to validate the project's research. The project will combine the expertise of some of Finland's top academic researchers from Tampere University of Technology; VTT Technical Research Centre of Finland Ltd; Åbo Akademi University; Aalto University; the University of Turku; and leading members of the maritime cluster including Rolls-Royce, NAPA, Deltamarin, DNV GL and Inmarsat," said Rolls-Royce.

Cruise ships

Virgin enters cruise

In the idiosyncratic world of the super-rich having an airline, railway business and mass communications empire would be to simply miss a trick.

Richard Branson needs a superyacht to keep up with the Rothschilds and Abramovich's and he has trumped them all by ordering three. Virgin Cruises has signed a letter of intent with the Italian yard Fincantieri to build the 110,000gt units.

The ships will have 1,430 cabins with space for 2,800 passengers and 1,150 crew members and are scheduled for delivery in 2020, 2021 and 2022.

"This is a very exciting day for Virgin and travellers around the globe", said Sir Richard Branson, founder of the Virgin Group. "We now have the right partners in place to build a world-class cruise line that will redefine the cruising experience for good." *NA*


CLORIUSCONTROLS.COM

IGF Code heads packed MEPC Agenda

The IMO's Marine Environment Protection Committee and the Maritime Safety Committee had packed agendas for the meetings in May and June with a new mandatory code for ships fuelled by gases or other low-flashpoint fuels adopted at MSC and other issues including cyber security matters and passenger ship safety, *writes Sandra Speares*.

While many operators have been exploring the use of alternative fuels such as LNG in recent years, particularly as a result of the new regulations on emissions, gas and other low-flashpoint fuels pose their own set of safety challenges, which need to be properly managed. The IGF Code aims to minimise the risk to the ship, its crew and the environment when using alternative fuels.

The amendments to SOLAS chapter II-1 include providing a methodology for alternative design and arrangements for machinery, electrical installations and low-flashpoint fuel storage and distribution systems and new regulations to require ships constructed after the expected date of entry into force of 1 January 2017 to comply with the requirements of the IGF Code.

The Code contains mandatory provisions for the arrangement, installation, control and monitoring of machinery, equipment and systems using low-flashpoint fuels, focusing initially on LNG.

It addresses all areas that need special consideration for the use of low-flashpoint fuels, taking a goal-based approach, with goals and functional requirements specified for each section forming the basis for the design, construction and operation of ships using the relevant type of fuel.

Other amendments clarified the provisions related to the secondary means of venting cargo tanks in order to ensure adequate safety against over- and under-pressure in the event of a cargo tank isolation valve being damaged or inadvertently closed. The expected entry into force date is 1 January 2017.

The MSC also approved guidance for watertight doors on passenger ships that may be opened during navigation which includes a procedure for determining the impact of open watertight doors on passenger ship survivability, technical standards for watertight doors on passenger ships among other requirements.

The long-term action plan on passenger ship safety was updated, to include consideration of the inclusion of inclinometer measurements within all voyage data recorders; development of more detailed assessment criteria for recognising manning agencies and development of guidelines on the appropriate assignment of trained crew to emergency duties; and development of guidelines for comprehensive risk assessment, passage planning and position monitoring; effective bridge resource management and the removal of distractions.

The MSC approved the MSC.1/Circ.1394/Rev.1 on the generic guidelines for developing IMO goal-based standards (GBS). The revised generic guidelines specify structure and contents of functional requirements to be used in GBS and give examples. The guidelines also describe the process for the development, verification, along with the implementation and monitoring of GBS to support regulatory development within IMO.

GBS are defined as high-level standards and procedures that are to be met through regulations, rules and standards for ships. GBS are comprised of at least one goal, functional requirements associated with that goal, and verification of conformity that rules and regulations meet the functional requirements including goals.

Under the GBS standards, construction rules for bulk carriers and oil tankers of classification societies which act as recognised organisations, or national administrations, must be verified, based on the guidelines for verification of conformity with goal-based ship construction standards for bulk carriers and oil tankers.

The MEPC also had a packed agenda for discussion in May considering the data collection system for the fuel consumption of ships.

A proposed text would cover ships of 5,000gt and above collecting data, to include the ship identification number, technical characteristics, total annual fuel consumption by fuel type and in metric tonnes. The methodology for collecting the data would be outlined in the ship specific Ship Energy Efficiency Management Plan (SEEMP).

Data would be aggregated into an annual figure and reported by the operator to the flag state which would submit the data to an IMO database. Access to the database would be restricted to member states.

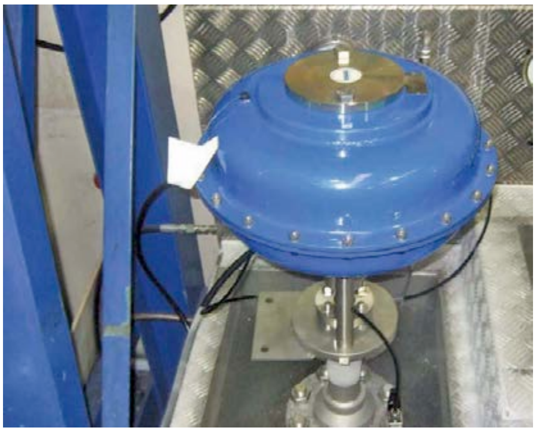
Commenting on the MEPC meeting in May RINA said that the correspondence group established to look at measures that enhance energy efficiency recommends that all ships above 400gt/5000gt submit annual consumption of fuels of all types used.

"The committee engaged in intense discussion on whether the data submitted should include some measure of transport work. This would enable some measure of transport efficiency to be derived and was resisted by many delegations. There was also discussion on whether the data collection should be mandatory or voluntary. This decision was deferred until full details of the data collection protocol have been agreed. *NA*

Valves

HHI opts for Bestobell valves

Greek owner Gaslog, which has ordered two 174,000m³ LNG carriers for 2017 delivery, from the Korean yard Hyundai Heavy Industries (HHI), will see its vessels fitted with Bestobell Marine's cryogenic Globe and Check valves.



A pneumatically actuated globe valve during cryogenic testing

The order from HHI follows a significant period of product development from Bestobell which has developed flanged valves to HHI's specification.

"This involved a great deal of innovation to create new patterns and tooling for casting and machining the valve bodies, working closely with HHI's design department. The contract also involved the design and approval of a new smaller version of Bestobell Marine's unique FLIV (float level isolation) valve. The new DN150 size valve will be suitable for the smaller secondary monitoring floats that HHI uses for the back-up cargo level gauging system," said a company statement.

Bestobell Marine is the marine division of Bestobell Valves, which has produced cryogenic valves for industrial gas applications for more than five decades and has had marine LNG experience for 15 years.

Bestobell valves are used on LNG Carriers, FLNG (Floating Production & Storage Units) and FSRUs (Floating, Storage & Re-gasification Units). The company designs and produces valves to meet specific requirements in the marine sector and has supplied cryogenic valves to a majority of the major shipyards building LNG Carriers.

www.bestobellvalves.com

EGR

MAN approves Alfa Laval treatment system

Danish engine designer MAN Diesel & Turbo has approved Alfa Laval's PureNOx water treatment system for use in its Exhaust Gas Recirculation (EGR) unit, which cleans NOx from marine diesel exhaust.

The MAN EGR will allow vessels fitted with two-stroke marine diesel engines to meet IMO Tier III NOx regulations which will become effective in January next year.

Alfa Laval said: "In 2012, Alfa Laval signed a cooperation agreement with MAN to develop the water treatment system for cleaning scrubber water in their EGR system. PureNOx not only prevents soot and compounds derived from the exhaust gas from accumulating in the EGR scrubber and corroding the engine, but also enables the bleed-off of clean water overboard in compliance with IMO criteria."

According to Alfa Laval PureNOx can be easily installed and is compact so can fit into small spaces within the engine room, while the EGR is integrated with the engine. This simplifies ship design and reduces installation time and costs, says the company.

In addition the company says, "MAN is now moving quickly towards EGR system commercialisation. And Alfa Laval is keeping pace, introducing the next-generation of PureNOx Prime water treatment system, which minimises the amount of sludge for onshore disposal." PureNOx Prime, which is smaller than the original system will be available by the end of the year.

www.alfalaval.com/marine

Monitoring

DNV GL approves emissions monitor

Parker Procal's Continuous Emissions Monitoring Systems (CEMS), the Procal 2000 emissions analyser, has been certified by class society DNV GL. The certification verifies that the system meets MEPC 184(59) Chapter 6 on emission testing of CO2 and SOx, as well as the requirements of the revised MARPOL Annex VI and NOx Technical Code 2008.

The system will allow ship operators to verify that the emissions from their vessels are within the set regulatory limits in Emission Control Areas (ECA)

"The Procal 2000 is an in-situ analyser which analyses the gases from the combustion of residual and distillate fuel. It also measures the water content of the exhaust so that CO_2 and SO_2 can be reported on both a wet and a dry basis, demonstrating compliance

Demand for emissions analysis tools is on the rise following the implementation of Emission Control Areas

with ECA regulations in port and in international waters," says the company.

Measuring up to six exhaust gases including SOx, CO_2, NO and NOx, "analysers are connected to a data acquisition system, which displays, data logs and re-transmits the monitored concentrations and SOx: CO_2 ratio - in accordance with IMO regulations - without manual intervention."

According to Parker Procal it has doubled its CEMS production capacity in response to industry demand. The company doubled its revenue as a result of the exponential increase in orders and continues to work with several leading scrubber manufacturers.

www.parker.com

Software

3D model sharing cuts costs

AVEVA and DNV GL have made a breakthrough that will allow the two companies to share 3D models between their software systems.

AVEVA said: "The new functionality, initiated by AVEVA to respond to the demand of the market, allows users to transfer AVEVA hull models into DNV GL's Sesam GeniE for strength assessment and code check according to DNV GL Rules. Now users can significantly reduce the time and effort spent in early design of ship hulls and offshore floaters, as they save the extra man-hours it takes to create separate analysis models from scratch in two different systems."

According to DNV GL the increase in finite element analysis required as a result of the development of the harmonised common structural rules (CSR-H) will mean the new sharing capability will cut the time spent duplicating work and thereby cut costs. The systems are appropriate for all ship types.

"The breakthrough is based on the advanced development of AVEVA Marine's capabilities, where a highly detailed 3D design model is idealised and translated into a finite element method (FEM) 3D model, including the connectivity of structural components and the finite element mesh needed to calculate structural behaviour. With the new and powerful advanced mesh editing features in Sesam GeniE, it is then possible to quickly add loads and to refine the mesh, enabling accurate and effective structural analysis," said AVEVA.

www.aveva.com

Software

KR launches software support for CSR-H

Asian class society the Korean Register (KR) has completed a major overhaul of its SeaTrust-HullScan software which analyses a vessel design's structure making sure that it meets the Harmonised Common Structural rules.

KR says, "As CSR-H includes a significant expansion in the scope of the direct strength analysis, more time and resource are required. The new SeaTrust-HullScan incorporates additional functionality to support modelling through interfaces with the specialised 3D CAD systems (AVEVA Marine, Smart Marine 3D and others) which are widely used in most shipyards in Korea. This radically reduces the time spent applying the requirements of CSR-H. Additionally, the automatic generation of a fine mesh model on location also saves many man-hours."

The new system offers functions that will optimise design and review data so that calculation results can be analysed with a single click. Correct analysis and evaluation of results is delivered through automatic generation of buckling panels based on Finite Element Methodology (FEM).

Initially launched in 2013 SeaTrust-HullScan has been adopted by most Korean shipbuilders and naval architects.

Commenting on the new version, Dr Kim Chang-wook, Executive Vice President of KR's Technical Division said:

"The unique feedback system built into the software encourages an open dialogue with our customers and is helping them make full use of the new solution. I am confident that SeaTrust-HullScan will help our customers generate rapid and more accurate modelling"

Both the CSR-H for Bulk Carriers and CSR-H for Tankers will become effective from 1 July 2015, one year earlier than IMO's mandatory application date.

www.krs.co.kr

Pipes

Pumping up the pipes

Purging pipes for maintenance is easier with inflatable Pipestoppers which block pipes in order for work to be carried out.

Pipestoppers operate as 'overnight stoppers' providing a barrier to the fluid in the pipe to allow for welding or other work. The inflatable bags come in a number of sizes, from 25 to 2,440mm, and can be dressed in heat resistant covers to protect against high temperatures while there is also a range of specialised inflatable rubber stoppers that are suitable for use with all hydrocarbons, gases and liquids.

"In machining applications, they can be inserted below a horizontal flange on a vertical pipe, to prevent machining fluid from falling below into expensive machinery such as pumps and turbines.

"When welding large tanks and vessels, stoppers inflated with air can dramatically reduce the volume inside, so that the argon purging process takes little time and uses the minimum of expensive gas. The stoppers pay for themselves in one weld and can be used multiple times.

"Other applications include leak testing of pipework systems, whether commercial, domestic or industrial, on site thermoforming of bends in plastic materials and fiber-optic constructions projects," says Pipestoppers, a Division of HFT.

Inflatable-Stoppers-PSI-PHO-24C-Spherical-Range

The inflatable stoppers are manufactured with a strong internal inflatable bag covered in waterproof sewn polyurethane coated nylon for low friction and to prevent the production of static electricity or accidental sparking. No high-pressure equipment is needed for inflation.

www.huntingdonfusion.com

Engines

The pressure's on

IMES says it has developed advanced software functions for its electronic pressure indicator EPM-XP, which is an accurate, light-weight, and easy to use hand held electronic device, designed for periodic monitoring of cylinder pressure on diesel engines.

The IMES system can record cylinder pressure values on up to 20 cylinders on two-stroke engines operating at speeds of up to 300rpm and on four-stroke medium- and high-speed diesels from 200 to 1500rpm.

Now IMES optimised its EPM-XP software by developing a new software algorithm to calculate compression pressure (Pcomp) automatically on 4-stroke engines according to their shipping companies' requests, the system already offers automatic calculation on two-stroke engines.

Due to this new way of calculating Pcomp on four-stroke units the indicated power (IPOWER) per cylinder will be evaluated automatically with a high accuracy, says IMES. Both Pcomp and IPOWER, will be displayed on different diagrams in the EPM-XP visualisation software.

The new software functions have been successfully tested using IMES' database which uses data of various four-stroke engines from their customers worldwide.

More than 1500 EPM-XP units are now in use and that demand is expected to rise as engines must be balanced optimally in order to comply with IMO TIER III limitations on NOx and SOx discharges in Emission Control Areas.

www.imes.de

Hull cleaning

Danes approve HullWiper cleaner

Three Danish ports, Copenhagen, Kalundborg and Fredricia, have approved the use of GAC EnvironHull's underwater HullWiper system for cleaning hulls while a ship is in port.

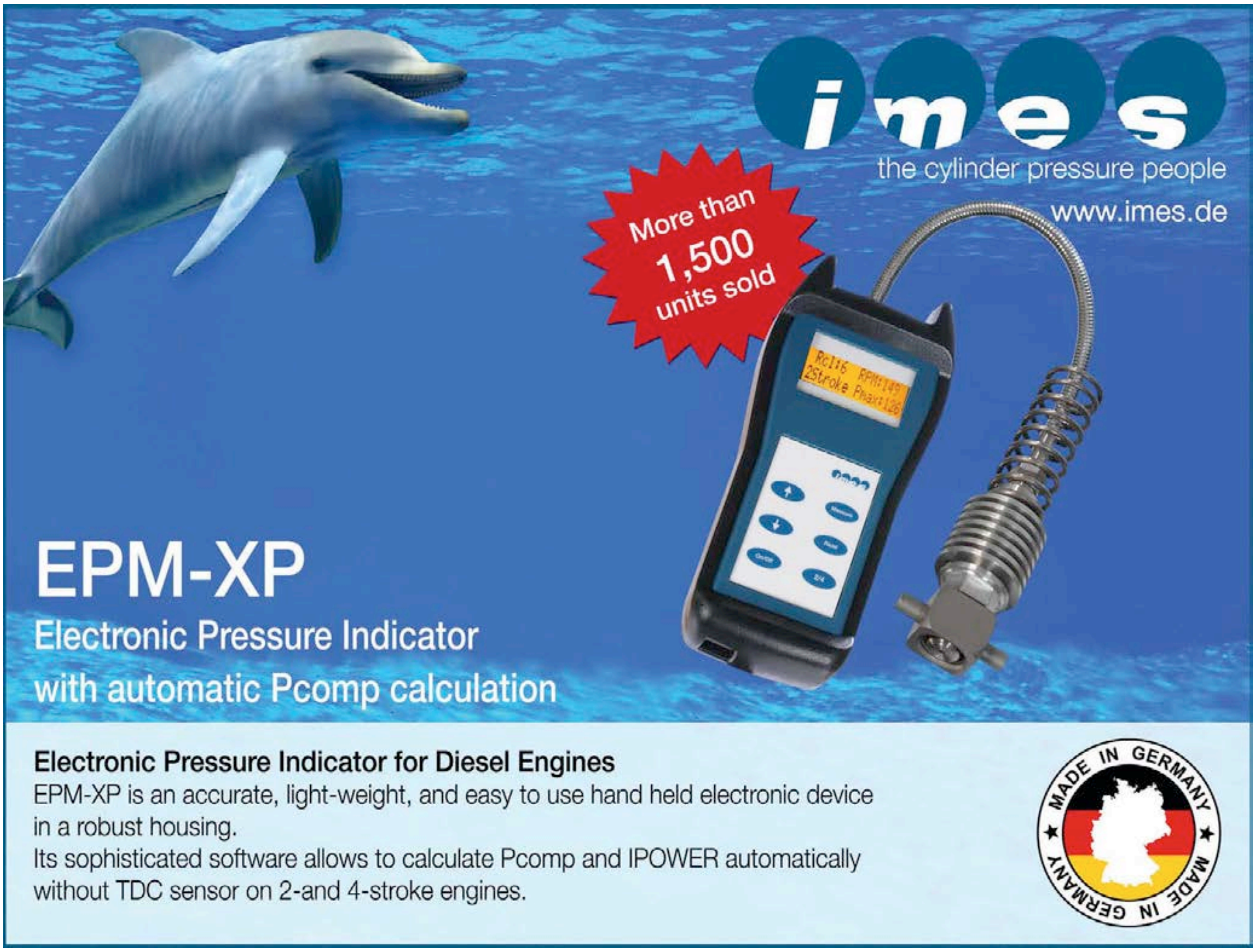
The system, developed by GAC, is diver-free and "the ROV can clean up to 2,000 m² of hull per hour without causing any damage to anti-fouling surfaces, due to brushless technology which uses adjustable pressure water jets to remove marine fouling. As no divers are involved, cleaning can take place alongside a vessel during loading or discharging operations, and any risk to life is significantly reduced. HullWiper cleans about five times faster than conventional cleaning methods with divers, reducing cleaning time by approximately half," says the company.

Any residues or marine organisms from the hull cleaning process are collected by the system and are disposed of rather than being returned to the sea.

The latest Danish approvals expand the service in Scandinavia following the approval of the ROV to clean hulls at Gothenburg, Sweden in 2014.

HullWiper was originally launched in the Middle East in late 2013 and it is now available at the ports of Dubai, Fujairah and Sharjah in the UAE and Sohar in Oman. It entered the European market last year, and was launched in Singapore and Malaysia in June 2015.

www.gac.com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with automatic Pcomp calculation
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EPM-XP is an accurate, light-weight, and easy to use hand held electronic device in a robust housing.
Its sophisticated software allows to calculate Pcomp and IPOWER automatically without TDC sensor on 2-and 4-stroke engines.
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Our software comes with:
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- Free updates
- Online help & tutorials
- No maintenance charges
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- Ship Motions & Sea Sickness Prediction
- Powering Prediction & Propeller Design
- Sailing Yacht Performance Prediction
- Onboard Loading
- Hull Scantlings ISO 12215-5
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DNV GL, man and boy

Having safely seen through the initial stages of the merger of DNV and Germanischer Lloyd DNV GL, Group President and CEO Henrik Madsen will retire on 1 August and Remi Eriksen will lead the group into the next phase of its development. In an exclusive interview Eriksen tells *The Naval Architect* his expectations for the future

Merging two large companies can be tough as cultures and software clash bringing tensions from within the group to the surface. Often from the outside the first idea of any difficulty is through an eruption of disgruntled former staff.

At DNV GL there has been little to suggest friction, but overall the impression is that the merger has been relatively smooth; this may be partially because the company did not shed staff as a result of the merger. Systems integration, an area which often raises the hackles within the staff group, also appears to have been relatively painless. This is a fine tribute to the outgoing president Henrik Madsen whose management of the merger process, along with his senior team, has proved to be smooth and efficient.

It is important for the momentum of the merger to be maintained and in this context continuity is a must for the company to preserve the drive that has evolved. In promoting Remi Eriksen from Executive Vice President (EVP) to Group President and CEO and following that with the promotion of Tor Svensen to EVP and the appointment of Knut Ørbeck-Nilssen to succeed Svensen as CEO of its Maritime business area, that continuity has been maintained.

Remi Eriksen, incoming DNV GL Group President and CEO, believes that the industry must act together to meet the challenges posed by Big Data

Knut Ørbeck-Nilssen (left) has taken over as CEO of DNV GL's Marine division while Tor Svensen (right) has been appointed Executive Vice President

Bridging the Madsen and Eriksen eras has been the work of more than 15 months, so far, to unify the two independent companies' rules. "At the moment you still have either DNV class or GL class, but from January [2016] it will be DNV GL rules," explains Eriksen.

Key designers, yards and owners are now testing the rules to make certain that they are robust. However, some of DNV GL's rules, including those that cover container ships, require higher standards than the standard regulations, he says.

Rules are about safety and safety is the raison d'etre for all class societies, but "there are still too many seamen killed" at sea at the moment Eriksen says. In the future there will be technical advances that will minimise the impact of human error, with human intervention seen as the major cause of accidents at sea.

Eriksen is putting a lot of faith in the development of new technical fixes that will drive the industry into a safer future. He points to accidents such as that which befell Concordia, where a catastrophic decision by those navigating the ship led to disaster.

"I can see that technological trends will make the impact of human error smaller – systems will intervene – systems will spot dangerous situations before they happen," he explains.

Digitisation will help the shipping industry with a number of issues, including safety, maintenance, vessel optimisation and the value chain, which he says is particularly important for container ships.

A digital revolution will also bring new difficulties, he believes: "When a ship becomes more connected it is opened up to other problems such as cyber security risks, wars in the future will include cyber-attacks."

Perhaps more pressing will be criminal behaviour that will also be a problem as criminals become more adept at using the cyber-sphere to e-burgle operators and owners. "Crime will happen," says Eriksen philosophically, "but we can protect and mitigate that risk."

The acquisition of Marine Cybernetics, in May last year, is an attempt to develop systems that are reliable, safe and of high quality, explains Eriksen, so that DNV GL can address the challenges thrown up by the shift to a greater digitalisation. "As an industry we must look at the software component, both in terms of reliability and vulnerability," he says, echoing the sentiment shown by the outgoing International Association of Classification Societies chairman Philippe Donche-Gay at his final press briefing in June.

The acquisition of the Norwegian software company is DNV GL's move to develop secure systems, but Eriksen believes that, "as an industry we must look at the software component of operations."

Those systems are not just about protecting vessels, but also developing operations using an increasing amount of data that is being collected from each vessel as it sails. Eriksen believes that Big Data is not necessarily the answer. "It is how we can use that data smartly, which is not just important for a voyage, but also for the supply chain."

He argues that the use of Smart Data could reduce waiting times, and improve fuel efficiency, giving benefits in emissions to the atmosphere as well.

The future, however, will see a mix of fuels being used with ships adopting fuel choices by trade. In what Eriksen calls "hybridisation," ships, he says, will be capable of operating using either diesel and battery power or gas and battery power.

Electric power will increase in the future, Eriksen believes, as the technology improves. "The costs of using battery power have halved in the last seven years and they will halve again over the next five years," he predicts.

He says that electric power offers an "immediate response" when operating a vessel and "reduces the peaks [in power demand] to the system". This can be useful for manoeuvring near port and can "reduce fuel use by a further 20%," he claims.

Eriksen believes that coastal vessels powered solely by electricity are likely to be developed in the medium term, but he says, deepsea vessels will need to stick to hybrid solutions. "Cost and power intensity are important in the development of battery power rather than size and weight, but if you can reduce the size and weight also, it would help," he reflects.

Over the past 20 years Eriksen has worked and developed his knowledge in the oil and gas, maritime and renewable energy industries and has been a member of the Executive Committee since 2006. *NA*

Guangzhou's grand plan

Guangzhou, the southern gate of China, has been an important oceangoing port for more than 2,000 years. The commercial city has benefited from the coastal culture and experience of being part of the offshore Silk Road. It is now looking to develop into an international maritime centre. Kuang Zhanting reports

The port of Guangzhou trades with more than 400 ports in over 100 countries and regions. The world's top 20 shipping companies have established 49 international container liner services in the Nansha port area in Guangzhou and shipbuilding cluster has been developed around Guangzhou in the Pearl River estuary. In 2014, throughput of Guangzhou port reached 16.6m TEU, up 6.9% year-on-year, ranking eighth in the world.

Guangzhou has now stepped up its efforts to establish itself as an international shipping centre and is promoting the city's transformation and upgrade. At the sixth plenary session of the 10th Guangzhou City Party Committee, Ren Xuefeng, the regional Communist Party Secretary, said that Guangzhou had to speed up the building of an international shipping centre and form a three-year action plan.

At a recent consultation conference themed "Action Plan 2015-2017, to build an international shipping centre in Guangzhou" (the action plan), experts have come up with ideas such as cruise tourism, building a Guangzhou merchant fleet, establishing Guangzhou-based international shipping conglomerates, speeding up local infrastructure development, improving existing port logistic system and providing modern high-end shipping services.

Pearl River at night

Building a local fleet

As the world's and China's economies have both entered a new stage, the cargo transportation sector has to face new challenges. That is why the shipping market has remained slow in recent years. While economic globalisation cannot be stopped, there has been no fundamental change in the demand and supply for shipping. According to experts from the port authority of the Port of Guangzhou, new government strategies and the commencement of infrastructure projects in the Pearl River Delta are expected to drive demand for bulk cargo which is expected to help revive the shipping sector. If the industry can seize the opportunity, it will be easier for Guangzhou to turn itself into an international shipping centre.

The strategies in the action plan are to set up and nurture key local port and shipping companies, encourage them to compete in the international market and to support Chinese companies, particularly local companies such as Guangzhou Port Group and Sinotrans.

Guangzhou proposes to build its own fleet. The idea is to have local corporates such as Guangzhou Port Group, Guangdong Province Navigation Holdings Company Limited, and the shipping joint venture of energy conglomerate Guangzhou Development Group Co Ltd and China Shipping Development Co Ltd to fund and set up companies to run ocean-going container liner services.

One of the weaknesses of Guangzhou's shipping sector is that it lacks a locally based sizeable international shipping enterprise. This issue cannot be ignored and the city is addressing it with the help of the three local companies: Guangzhou Port Group, a large port operator in Guangzhou; Guangdong Province Navigation Holdings, a Guangzhou-based shipping and transportation group which is adept in near-sea transportation but has relatively limited international experience; and the Guangzhou Development Group-China Shipping joint venture whose key mission is to fuel the city's electricity supply, while at the same time develop an ocean-going fleet with the expertise of China Shipping.

Guangzhou's local fleet concept has sparked controversies in the nation's shipping sector. One strand of thought is that a local fleet would provide vertical integration advantages that the city could leverage on China Shipping's expertise in shipping and the city's local business networks. The collaboration between the port and a local fleet would help the setting up of stable international liner services and an international shipping service network and sustain momentum to fuel the long-term development of the port city.

However, investing in a local fleet could bring huge financial pressure and occupy limited resources as the international shipping market is still sluggish with supply still exceeding demand, and shipping has a rather low profit rate and long profit cycle. They also think it would introduce further competition into an already fiercely competitive market. An alternative would be to attract large shipping companies to set up branches in Guangzhou and focus on improving software such as raising the standard of shipping services of the city.

Appropriate advancement

Guangzhou has been looking to turn itself into an international shipping centre for a long time, but now the CPC Secretary has released a concrete strategy. According to the action plan, the initial steps are to improve the port logistics system and speed up infrastructure development.

Ye Tiren, senior consultant of port affairs and marine economics at Singapore's Nanyang Technological University, said that port cities, facing challenges such as the regionalisation of their hinterland, an increasingly competitive international market and more stringent demand on supply chain management, have to place huge capital investment on re-planning. The port of Los Angeles has spent several billion US dollars on reclamation and reconstructing its terminals.

The Guangzhou action plan proposes a strategy of advancing port infrastructure construction in order to utilise the existing advantages of the port. Nansha is the key port area of the port of Guangzhou. Phases I and II of the Nansha development will have 10 box terminals of 100,000-tonnes each. Phase III has two 150,000-tonne container terminals that commenced operations on 27 September 2014, and four other 150,000-tonne terminals being built. Guangzhou port has a natural sea channel which has been dredged wider and deeper since 1996. Nansha port area has a 17m depth sea channel which can accommodate the largest existing containerships. The world's largest 19,100teu containership, *CSCL Globe* berthed at Nansha in 2014.

Guangzhou port has speeded up the construction of Nansha phase III, targeting to complete four 150,000-tonne terminals by the end of this year. The port has also commenced construction of Phase IV hoping to enhance its box handling capacity and satisfying clients'needs. It will also carry out the widening of channel and construction of a cruise terminal, a river-sea terminal and the Shazaidao near-sea terminal.

The idea of appropriate advancement is relevant to the scale of infrastructure and rationale behind port development. According to the "Guangdong Province Green Port Action Plan 2014-2020" (the green action plan), Guangzhou city will emphasise several aspects of its port master plan, namely: eco-protection, utilisation of coastline resources, development of publica terminal, optimisation of port logistic systems, promotion of mid-stream operations and rail-water transit.

Based on its master development plan the city will also reorganise highly polluting terminals that have a high energy consumption and low coastline utilisation in order to optimise port functions. New 100,000-tonne cruise terminals will be equipped with onshore power supply facilities. It is also the city's priority to provide onshore power supply for newly built container terminals. Guangzhou port has been listed as one of the major participants in the "green port movement". The port will start the trial for LNG-powered tug boats and implement a bulk terminal dust pollution control project.

Targeting high-end shipping services

There has been a consensus among industry players that the city should expand its shipping services and cruise- and yacht-related services in order to fill the gap in high-end shipping services market. Ye Tiren believes that Guangdong Province already has an edge in port operations, ship supply, ship equipment and accessories sales and inland water transport etc. The province should launch into higher-end segments such as ship repair, marine education and training, marine logistics and related services, shipping enterprises, ship management, marine R&D and information communications, classification societies and marine surveying and cruise-related businesses, according to Ye. He also thinks that the city should enter high value-added fields and areas that require specific knowledge, such as ship brokerage, ship leasing, insurance and reinsurance, P&I, marine legal services and marine financial services.

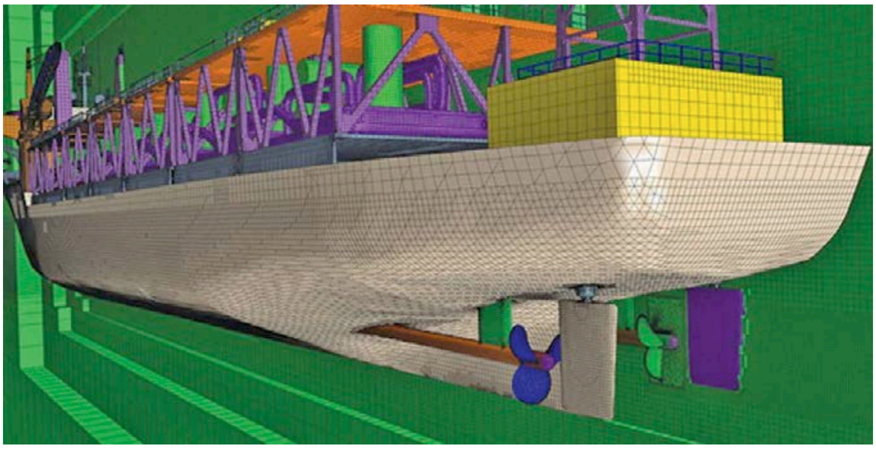
According to the action plan, the city aims to strengthen its soft power through expanding the Guangzhou Shipping Exchange and implementing the Nansha cruise terminal project. Guangzhou city has teamed up with the Guangdong Province to run the Guangzhou Shipping Exchange and support the exchange to build a shipping big data centre, market surveillance centre and exchange centre. The city also hopes to use the shipping exchange as a platform to launch a variety of modern shipping services such as maritime insurance, ship registration, legal consultancy and arbitration services.

The city government of Guangzhou has approved the Port of Guangzhou's request to strengthen and expand Guangzhou Shipping Exchange. The Guangzhou Shipping Trade Co Ltd was incorporated on 23 March 2015. The corporation provides services such as research, trading, finance, insurance and third party clearing in Nansha free trade zone.

Meanwhile, the cruise business is expected to be a key driver of the city's expansion in high-end marine services. Nansha International Cruise Terminal has been listed as one of the highlight projects of the city in 2015. With an aggregate area of 499,800m^2, phase I of the terminal will have a 100,000-tonne and a 225,000-tonne berth, a main building, hotels, a commercial centre and a high-end duty-free shopping mall. *NA*

Are towing tanks dead in the water?

Since the first commercial ship basin was commissioned in 1883 towing tanks have provided naval architects with a trusted method of predicting the performance of a ship at sea. They are used for both resistance and propulsion tests and to determine how much power is necessary to achieve contracted speed levels. Is CFD ready to replace the tank?



Trimmed hexahedral mesh around the hull and rudder with polyhedral overset mesh around the propeller

Developments in computing hardware and the software used in Computational Fluid Dynamics (CFD) will see the traditional methods of designing ships largely superseded by modern technological advances, says CD-adapco's Director of Marine Dejan Radosavljevic.

He believes that the development of CFD software and the verification of calculations will bolster industry confidence in CFD and that in turn will speed up the design process substantially and reduce costs significantly as a result.

In effect the development of CFD techniques allows designers to view the interaction between all of a vessel's key areas on the hull and the water, rather than just individual elements such as the rudder or propeller in isolation and it allows calculations to be made at full scale, rather than having to face the difficulties and uncertainties of scaling experienced through model tests.

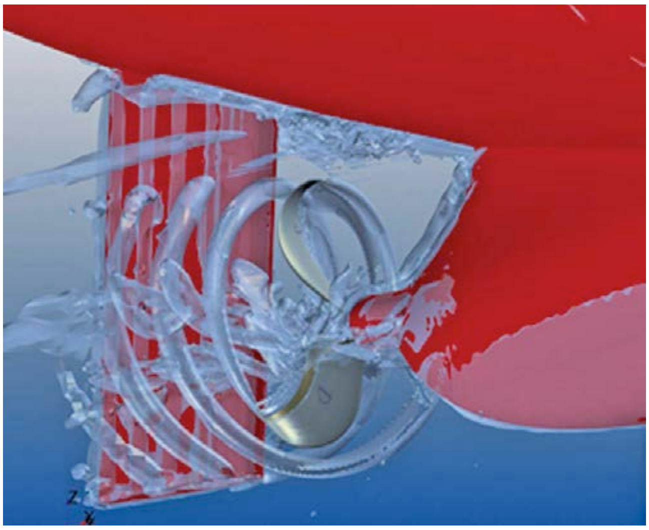
"Vessel performance depends on the hydrodynamic interaction between the hull, its propulsion system and its rudder with all these elements combining to interact with the environmental conditions.

"The flow past the hull influences the flow past the rudder, which in turn affects the quality of flow 'seen' by the propeller. While it is certainly possible to obtain useful design information from experiments (or simulations) that investigate these components individually, in order to predict the at-sea performance of a vessel with a high degree of accuracy, it is necessary to include all three components in a single model", says Stephen Ferguson of CD-adapco.

Ferguson adds that this is particularly important with the current demand for energy efficient 'green ships' which is driven by a combination of legislation and economic necessity. Energy savings of a few percent can significantly influence the operational viability of a vessel.

"However, the cost and effort of producing a model and testing it, means that towing tanks are usually deployed relatively late in the design cycle, verifying and fine tuning an established design, rather than providing engineering data that could be used to drive the design into different, better, directions. In addition, any novel solution tested at model scale has increased uncertainty of actual performance at ship scale due to deficiencies of the scaling process," Ferguson explains.

He goes on to say that CFD has matured into a credible alternative to tank testing, providing a "numerical model basin" that



Transient DES simulation of the self-propulsion of a bulk carrier using the tip modified Kappel Propeller showing flow around hull and propeller. Image courtesy of MAN Diesel & Turbo, Denmark.

can in principle be deployed at a much earlier period in the design process. That would offer naval architects a stream of engineering data that could be used to improve the design.

"CFD also carries the distinct advantage of result accuracy independent of the scale at which they are calculated," argues Ferguson. Until recently, however, that prospect has been limited by a number of challenges inherent in the CFD simulation process, but advances in CFD and hardware technology have addressed those concerns to the extent that fully featured numerical towing tanks are finally now a practical proposition.

Meshing

CFD simulations solve the fundamental equations of fluid dynamics, through a process known as "discretisation" in which a volume occupied by the fluids (both water and air) surrounding the vessel is subdivided into a number of much smaller control volumes (known as computational cells). Depending on the software used, these control volumes can be tetrahedra (four-faced pyramids), hexahedra (six-faced bricks) or polyhedra (control volumes with an arbitrary number of faces).

Constructing a computational mesh is one of the most important parts in conducting a CFD simulation, and always represents a compromise between accuracy and computational cost.

In practical terms, a fine mesh that is constructed from a large number of small computational cells provides a more accurate prediction than a coarse mesh of larger cells. However, a greater number of cells results in a larger computational cost, requiring more computer resources and longer simulation times compared with a coarser mesh.

Since the computer resources available for a given simulation are finite and, in order to be useful, simulation results must be provided within a reasonable time-scale, CFD engineers have to choose how they spend their cells wisely, deploying smaller cells in areas of high rate of change close to the vessel and its wake, transitioning to larger cells further away.

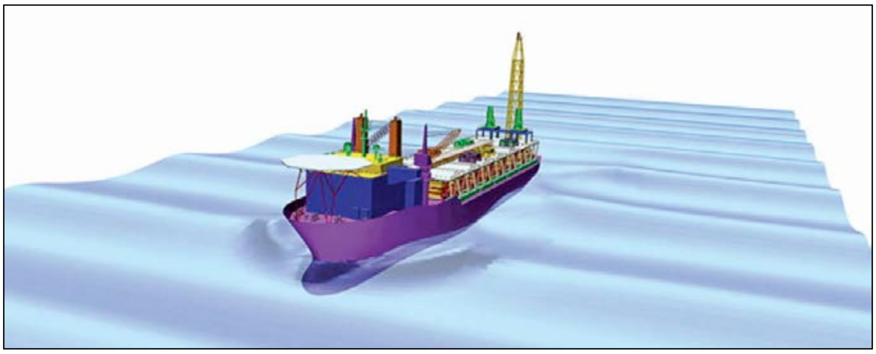
Historically, providing a computational mesh that is fine enough to capture the hull, rudder and propeller in a single simulation has been challenging, and engineers have often been forced to consider the components in separate simulations (and accounting for their interactions using boundary conditions).

However, recent developments in automatic meshing technology (that provide a high quality grid with minimal manual interaction from the engineer), computer hardware (which provides lower cost computational resources) and flexible licensing (which reduces the cost of running simulations across multiple processors) has made self-propulsion and manoeuvring tests a practical proposition.

Wave and water physics

In order to accurately predict the performance of a vessel, the numerical simulation has to correctly predict for both the influence of the vessel on the surrounding sea (wake predictions) as well as the increase in resistance caused by waves.

This represents a much greater challenge than the type of single fluid simulations that can be used to investigate an aircraft, land-vehicle, or fully submerged vessel.



STAR-CCM+ simulation of an FPSO in rough seas

Many CFD tools deploy a 'Volume of Fluid' approach that assigns a value of '1' to cells that contain water, and a value of '0' to cells that contain air. In cells marked '1' the physical properties of water are used, in the cells marked '0' the properties of air are used.

CD-adapco's software STAR-CCM+ deploys a "High Resolution Interface Capture" scheme to accurately capture the position of the free surface between water and air; this is necessary to prevent the free surface from diffusing (with cells that have a value that is somewhere between '1' and '0'). This method ensures that the interaction between the vessel and the free-surface can be accurately captured. STAR-CCM+ also provides a range of built-in higher-order wave models that can be used to test the vessel under realistic sea states.

Additionally, STAR-CCM+ includes an extensively validated cavitation model that can be used to predict and manage the phase changes caused by the propeller.

Vessel motion

Unlike the simulation of an aircraft or road-vehicle, which in ideal circumstances moves forward in a single direction, the forward progress of a ship is heavily influenced by the surrounding sea-state. Even in still water, establishing the dynamic position of the ship in relation to the sea surface ("sink and trim") is critical to providing accurate resistance predictions. In rough seas, the full motion of the vessel in six-degrees-of-freedom must be correctly accounted for, as the vessel pitches, rolls and heaves in response to oncoming waves.

STAR-CCM+ accounts for 6DOF vessel motion in an automatic manner. The "Dynamic Fluid- Body Interaction" model integrates the forces acting on the vessel at every time step, and adjusts its position (in all-six-degrees-of-freedom) accordingly.

"Adjusts its position" means moving the computational mesh, which historically has been a difficult proposition, and various methods have been used to account for this motion. For relatively small movements, the vertices of cells in the mesh can be adjusted on a step-by-step basis. However, for large movements, this becomes impractical as individual cells become highly distorted, leading to inaccuracies in, or failure of, the simulation.

STAR-CCM+, uniquely among commercial CFD codes, solves this problem using "overset" or "chimera" meshes, in which the mesh around the vessel is independent of the mesh used to represent the sea. This allows the simulated ship to move as much as necessary. Furthermore, it can be used to model the interaction between multiple vessels or objects, such as one ship moving independently in the wake of another, or the collision of two vessels. Also, with overset mesh, the rotation of the propeller and rudder motion, in addition to propeller pitching, can all be modelled in relation to the ship motion, leading to robust, accurate self-propulsion and manoeuvring analysis.

Former Lloyd's Register (LR) man, Radosavljevic, says: "Scaling up is a problem that in the past was overcome by the experience of the naval architect or towing tank and statistical data from ship trials, but traditional naval architecture can't reliably tell you how the newly designed vessel will perform; only CFD can give you those answers."

Radosavljevic points to the tests completed by Silverstream which showed that the air lubrication system that the company designed would offer substantial fuel savings. "Silverstream, validated by Lloyd's Register in full scale showed that CFD can work," he says.

According to Radosavljevic CFD does not need massive computing power to work, though he admits that the bigger the computer the better, because you get more complex models with each additional feature, such as hull appendages, propellers and cavitation information needing an increasingly fine mesh.

However, with design optimisation in CFD a naval architect can explore many variants and find which configuration will work the most efficiently. "You can't do that with model tests because you need a number of days to build a physical model, with CFD you set goals and criteria along with the objectives and constraints and the computer does the work. It simply can't be done without CFD," claims Radosavljevic.

"For example it was impressive to see how South Korean shipyards have embraced CFD," claims Radosavljevic, "it empowers them to innovate, allowing them to test ideas and that allows them to stay ahead of their competitors. Model testing cannot innovate in the way that CFD can."

Radosavljevic, however, does not discount the value of tank testing completely. "Model tests should come at the very end of the design process," he says, adding that "first you design the vessel using full scale CFD and then, if requested, you just demonstrate to the owner that the CFD calculations are correct using a small subset of model runs."

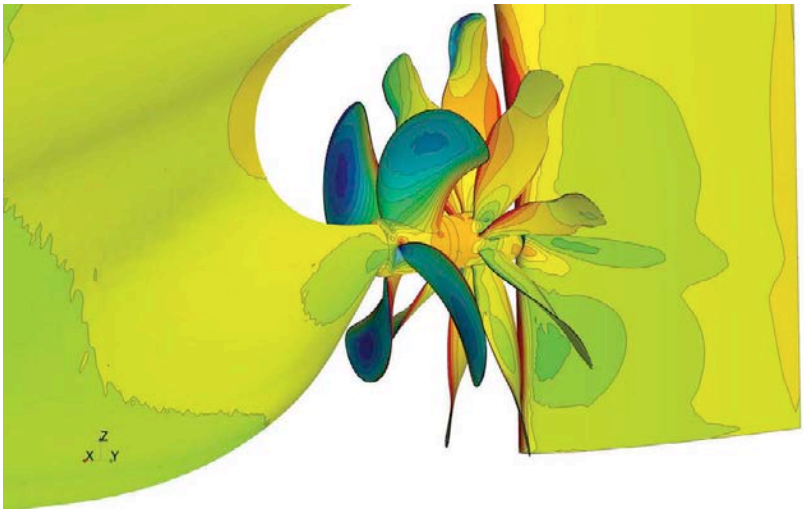
According to CD-adapco "the only barrier to the wide use of CFD in ship design is the industry confidence when compared to model testing." That trend will change as the use of CFD becomes more widespread and the benefits become better known. Towing tanks will still have a research, educational and validation role to play, but as CFD becomes more prominent the use of towing tanks in the design process could become less important, until they are eventually phased out altogether. *NA*

Why bigger is better in CFD

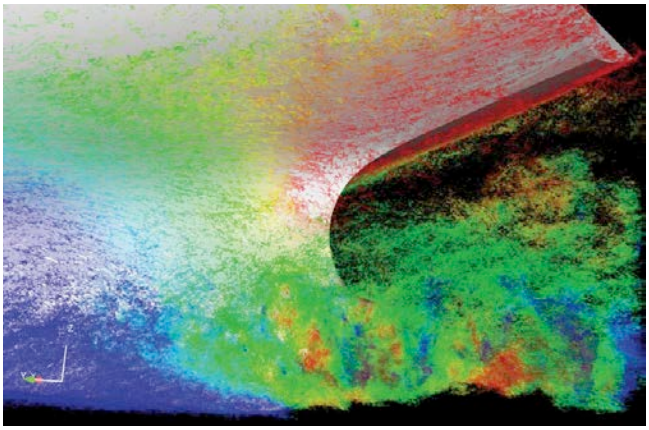
A revolution in computational fluid dynamics is expected with the growth in computing power driving the science. Volker Bertram of DNV GL explores how the developments will affect ship design

Computing power continues to grow exponentially, doubling approximately every two years. CFD (computational fluid dynamics) is one technology that particularly benefits from this development.

However, CFD is also particularly greedy in terms of computational power. And so far the scope of CFD analyses has grown at least as fast as computing power. But it is important to have a closer look at how CFD exploits growing computational power, and why it will need further growth for decades to come.



Direct modelling of propeller (and in this case Grim vane wheel) requires computationally more demanding transient CFD simulations; source DNV GL


Vortex structure in aft part of a tanker using LES simulation with 32 billion cells; source: SRCJ

Why do we need more computing power?
Computing power continues to grow – CFD greedily gobbles it up. Over the past decade, there have been some developments in state-of-the-art CFD projects which we may dub as "moderate gobblers", *Peric and Bertram* (2011):

- Increased level of detail in CFD models
  We model complete systems including more geometrical details. For example, we simulate flows around ships with appendages, such as bilge keels, propellers and rudders. We also use generally finer grids with more cells, sometimes simply because we can afford it.
- Transient flow instead of steady flow
  CFD analysis in the past was often for steady flow around the hull or perhaps the hull with a simple steady-thrust model ("actuator disc") for the propeller. While such simplified simulation models remain popular, we see increasingly transient flow models, i.e. models where the flow changes in time, e.g. due to the inclusion of a turning propeller with its individual blades.
- Full scale ("numerical sea trial") instead of model scale ("numerical towing tank")
  Model tests cannot respect all similarity laws; thus in some aspects, the flow around a ship model in a model basin differs from that around the real ship. For example, the boundary layer thickness is relatively thinner at full scale, leading e.g. to very different behaviour of propulsion improving devices. The thinner boundary layer requires smaller cells to be properly resolved. This in turn increases "cell count" and leads to higher demands in computational resources.
- Design for operational spectrum rather than for just a design point
  Traditionally ships were contracted and designed for design speed and design draught. But in reality, ships rarely operate at design point. Designing instead for a variety of speed-draught combinations has become best business practice. The analysis of a spectrum of operational conditions requires an order of magnitude more effort than a simple design point.

These improvements in our CFD analyses may lead to an increase in computational resources by a factor 10 to 100. This is "moderate" in comparison to two other developments that are expected to drift from research status to industry practice within the next decade or two. These "big gobblers" are:

- Optimisation
  In formal optimisation, thousands to tens of thousands of variants are investigated. The required computational resources

increase correspondingly. At present, we "solve" the problem by using steady-flow approximations and fewer variations for high-fidelity CFD analyses. Extensive formal optimisation and transient CFD analyses may gain yet another 2-3 percentage points in energy efficiency beyond current designs, but we may have to wait a decade before we see this in industry projects.

- Turbulence modelling with direct capturing of large eddy structures

  Turbulence modelling is a classic example of whether you like to see the glass half full or half empty. We have made significant progress in turbulence modelling for ship flow simulations. But still, there are many different turbulence models in use (all yielding variations in results) and turbulence modelling is a popular scapegoat if results are unsatisfactory.

There is wide consensus in the CFD community that LES (large eddy simulation) will defuse current debates and become the one turbulence model to bind them all. What is it and why don't we use it then? LES uses very fine grids and fine time steps to capture directly the significant turbulence structures (which differ between different flows) and a universal turbulence model only for the "background noise" in the turbulence. For ships, appropriate resolution in time and space may lead to computational effort that may be 1 million times higher than in current simulations. LES is, therefore, subject to research and may take two decades before drifting into industry applications for ship flows.

Divide and conquer?

The exponential growth in computing power has been based in the past mainly on miniaturisation of chips. In very simple terms: if your cable is half as long, your signal will arrive in half the time. First integrating elements on a chip and then downsizing all elements has made processors increasingly fast and powerful. Conducting lines on chips are now down to tens of nanometers. We just cannot continue making chips infinitely smaller. Once we reach thickness values of a few molecules, we have reached limits where we need to think of other strategies to make computers faster. In short, the key word is "parallelisation" instead of "miniaturisation".

Currently, the most powerful computer, Tianhe-2, capable of 33.86 petaflops, consists of some 3 million cores. (Your PC is likely to have two or four cores. DNV GL's parallel cluster is the biggest in the maritime world and has 7,600 cores.) The first computer capable of 1018 floating-point operations per second (1 exaflops) is expected to arrive around 2020. This so-called exa-scale machine is likely to have 300 times more cores than the Tianhe-2. In general, the architecture of future supercomputers will be much more parallel than in the past and colloquially dubbed "exa-machines".

New computer architectures will require new algorithms (or computing strategies). It is very similar to business life. Two people working side by side may get almost twice the work done than a single person. But 200,000 people require corporate structures with pyramids of organisation where sub-divisions work largely independently. Still, overhead costs increase and are a constant headache. Similarly in super-computing we will see domain subdivisions and groups of cores working closely together on sub-tasks with increasing portions of communication times needed. Academia and large CFD vendors are busy preparing for the new age of exa-machines, developing algorithms that will exploit "divide and conquer" approaches to sub-divide computational domains and tasks hierarchically to balance the computational load over very many cores.

Milovan Peric (CD-adapco) describes a roadmap to exploiting the capabilities of future exa-machines: "Once we get into the range of millions of cores, both solution algorithms and communication patterns will have to change – and this will require a closer collaboration of software and hardware developers. Just as we used to have 'maths-co-processors' in the early days of PCs to speed up mathematical operations, we may end up with 'com-co-processors' that will enable overlapping of communication and computation in order to cope with millions of cores."

Supercomputers for everyone

Nishikawa (2015) gives a glimpse of the future with his numerical propulsion tests for a tanker using LES turbulence modelling and the K-computer, the largest computer in Japan. The simulations use 30-60 billion cells and 200,000 cores in parallel. For perspective, this is 10,000 times the number of cells and cores we typically employ at present in industry applications. A decade may easily pass before such computing power becomes widely available in industry. However, we can start using "the cloud", renting computing power and the massively parallel software licenses required for such computations.

Examples of how this might work in practice are CD-adapco's "Power on Demand" or Numeca's "Numeca on Demand", *Hildebrandt et al.* (2015). This "pay-on-demand" approach could become a fundamental game-changer giving access to advanced CFD also for small and medium-sized enterprises. It is expected that all major CFD software vendors will offer licence schemes that make occasional use of massively parallel computing affordable for a wider industry public.

Exa-machine computing will not come overnight. There is rather unspectacular organic growth in computing power, as clusters are upgraded and extended virtually every year.

Thousands of "numerical sea trials"

"Prediction is very difficult – especially about the future," as Niels Bohr aptly said. Still it seems plausible that we will see more CFD and more sophisticated CFD, exploiting the opportunities which come with growing computer power. The classical towing tank test will be replaced by hundreds or thousands of "numerical sea trials" that assess design or operational variations in parallel; not tomorrow, not next year, but eventually. Think in terms of decades and it will happen. *NA*

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Survival of the Fittest

Super-computers are about to change the virtual world in which computational fluid dynamics exists. James Hawkes goes exploring and describes the changes that will revolutionise vessel design

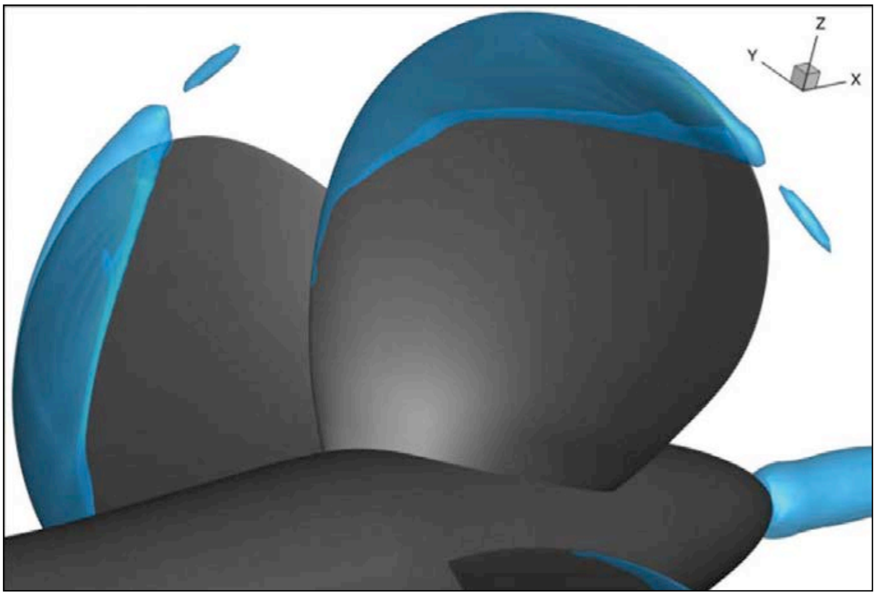
Super-computers are continually pushing the boundaries of technology, pursuing the exponential growth in performance enjoyed for at least two decades. This performance increase allows advances in physical modelling techniques that make unsteady, viscous Navier-Stokes solvers so powerful for research and development.

Tianhe-2, in China, is currently the fastest super-computer in the world according to the Top500 organisation – which tracks and studies the development of high-performance computing around the world. Tianhe-2 is capable of 33.86 petaflops per second (34-thousand-trillion operations-per-second), though it is not expected to hold the top spot for much longer.

The United States Department of Energy has commissioned a new supercomputer for 2018, Aurora, which will be capable of 180 petaflops. Technology is expected to allow construction of the first exa-scale machine, capable of 1 exaflops (10^{18} flops), by 2020. Overall, these computers continue to grow at an exponential rate, but under the bonnet there are significant architectural changes which developers must adapt to if they wish to use this new hardware.

CFD is on the cusp of major computational changes that will power the next generation of CFD software says James Hawkes

Figure 1: State of the art cavitation simulation in ReFRESCO, a joint-development CFD code pioneered by MARIN and multiple universities. (marin.nl)



The technology that drives these huge machines ripples down through the whole industry. Whether our CFD codes run on exa-scale super-computers, industrial or academic clusters, or under the desk in a workstation; the hardware will have changed to make use of the most efficient technology. The codes which can adapt to and exploit this hardware will see exponential growth in speed and capability. Those that don't will perish.

Next-generation computing

Until around 2004, the limitation driving hardware technology was peak clock frequencies. Individual cores could be made faster and more efficient (in terms of electrical power consumption) simultaneously by shrinking their transistors, and so manufacturers invested in shrinking technologies. As transistors continue to shrink, quantum effects allow electrons to 'jump' across the silicon in a phenomenon known as leakage.

Leakage current creates lower limits on the power requirements of cores, creating a 'power wall'. This power wall caused core clock frequencies to stagnate, and manufacturers turned to multi-core technologies to continue increasing total flop rates. Today, workstation processors such as Intel's Haswell-EX have up to 18 cores in a single processor. Parallelisation is increasing approximately 20-times faster than it used to; codes that were designed for modest parallelisation in the pre-2004 era will require serious modifications [1].

Seymour Cray, the founder of Cray Research once commented on the disadvantages of parallel computing: "If you were ploughing a field, which would you rather use: Two strong oxen or 1,024 chickens?" In a few years, CFD practitioners may have to employ 20,000 metaphorical mice.

To push core frequencies further, modern processors often have dynamic core clock rates; allowing cores to speed up temporarily – within the power envelope of the processor. This is cleverly marketed as a 'turbo' feature rather than a throttling feature. In future processors, these power management systems will become more commonplace, with much of the processor 'going dark' to stay within power limits. This *dark silicon* effect will create a highly heterogeneous system, which will wreak havoc on parallel computations which previously had good load-balancing.

Many machines, both at workstation and super-computer level, utilise accelerators alongside their standard processors. These may be in the form of graphics processing units (GPUs) or specialist co-processors. These accelerators feature many cores running at low frequencies (the latest Xeon Phi has 72 cores, and the latest GPUs have almost 5,000) – and as such they are a stepping stone to a many-core, heterogeneous era. Accelerators may not be a long-term solution, but they represent an architecture which will be here for the foreseeable future.

Further efforts to increase flop-rates have been via the re-introduction of vector processing at the sub-core level, similar to the array-processing of old. This allows multiple elements of an array to be operated on at once to provide yet more parallelisation. Modern compilers can perform some auto-vectorisation, though it is mostly up to the developer to exploit it fully.

As the cost of floating point operations has decreased, in terms of electrical power and time, many other parts of the computer have become a bottleneck. The cost of storing data, and moving data back and forth to memory, has become proportionally more expensive, only improving at half the rate of processor improvements. Similarly, the networks connecting the nodes in a super-computer have seen limited improvement. Fundamentally, transferring a byte of data down a copper wire has a fixed cost: it takes a fixed amount of electrical power and a fixed amount of time. As such, our efficient processors are starved by our inefficient memory systems. Developers must be careful of data locality, ensuring that data is stored physically close to the cores which operate on it in order to avoid unnecessary movement wherever possible.

Figure 2: Intel will deliver the US Department of Energy supercomputer, Aurora, in 2018. (Intel.com)

Overall, the ecosystem of high-performance computing is changing dramatically. The many-core era is approaching, and CFD codes must adapt if they wish to survive and thrive.

How can CFD survive?

Many CFD codes were fostered under the pre-2004 computing architecture, using message-passing techniques (sending packages of data between nodes) to allow inter-nodal parallelisation. As more nodes were added to super-computers, and more memory became available, these codes could naïvely use these extra nodes and increase the size of their meshes respectively. Developers were free to focus on physical modelling, enjoying higher resolution and higher speeds with relatively little effort.

Most of these codes are based on distributed-memory computing. That is, multiple copies of a process run on a machine, each with their own address space. This is a perfect system for inter-nodal parallelisation, where each node has its own memory; but when multi-core processors arrived in 2004 this method started to become outdated. CFD codes often advertise their near-perfect parallel efficiency at the inter-nodal level, but completely disregard multi-core scaling within a node, and this is where the real challenge lies. There are several efficiency losses when packing multiple distributed-memory processes into a single node, and this will be amplified by changes in technology:

- Memory Usage: Processes have a large memory footprint, and any data common to the entire CFD problem is duplicated within a node needlessly. The more cores and processes existing on high-performance computing nodes, the more memory is duplicated. In a typical simulation, each process may create up to 100MB of duplicated memory, which limits the amount of memory available for the actual simulation. With the number of cores growing twice as fast as memory capacity, this is a dangerous situation. Furthermore, sending messages between processes existing on the same node is an unnecessary waste of resources. It requires expensive copying of data from one process' buffer to another, whereas the target process could, in theory, directly access the data itself. It is the equivalent of asking your co-worker to pass you a document, when in fact it is already in your hand.
- Load Balancing: Most load-balancing is performed prior to a simulation to divide the computational mesh among the processes. Accurate load-balancing is important because the overall simulation can only progress at the rate of the slowest process. Changing this load-balance mid-simulation is expensive and complicated, but is usually implemented for codes featuring automatic mesh refinement.

This dynamic load-balancing is nowhere near efficient enough to handle the fine-grained fluctuations in core clock frequencies caused by dark silicon effects. Simulations on a many-core machine will be limited to the speed of the most throttled core at any time. Pessimistic estimates expect 50% of a machine to be dark by 2018, potentially doubling simulation time – again, a dangerous situation.

So what can CFD do to survive this? The most comprehensive method for dealing with this problem is to implement a hierarchical parallelisation scheme. For example, using one distributed-memory process per node, and exploiting multi-threading within that process, with the common programming standards being MPI (Message Passing Interface) and OpenMP (Open Multi-Processing) respectively. This allows all of the cores within a node to access the same memory and thus share the work of each process. Data does not need to be duplicated, which is favourable for memory capacity. No messages need to be sent between threads, which is favourable for data locality. Finally, the work of each process can be split dynamically, allowing faster threads (running on faster cores) to steal work from slower ones – thereby dealing with heterogeneity [2].

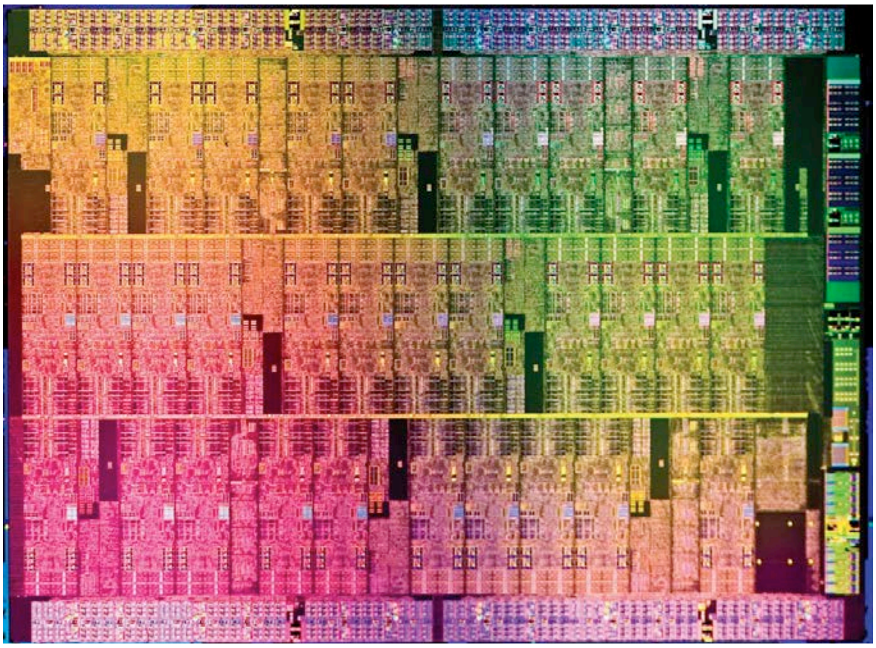
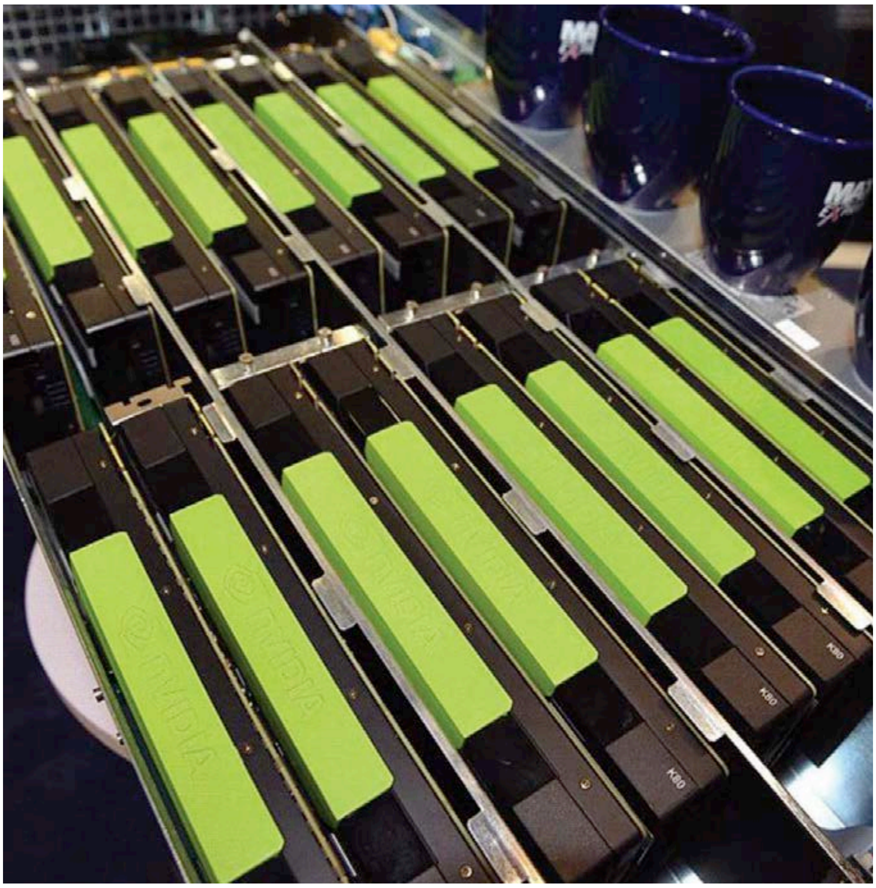


Figure 3: Silicon die of a prototype 32-core Xeon Phi co-processor. The 2nd-generation Xeon Phi, code-named Knight's Landing, will have 72 cores. (Intel.com)

Fig 4: An nVidia multi-GPU node with almost 80,000 cores. (nVidia.com)



This hierarchical parallelisation technique provides good support for many-core processors and co-processors, and can be mixed with GPU programming interfaces to provide good support for all types of accelerator. At a finer level, vectorisation can also be applied using OpenMP directives, though this comes with its own set of challenges to overcome. For structured meshes vectorisation is trivial, but for unstructured meshes careful optimisation must be performed, usually involving "padding" of data structures in order to make their memory-access patterns more uniform.

Fortunately, this hybrid scheme is easy to adopt – but it's only the tip of the iceberg. The CFD codes that stand out from the crowd will be the ones that capitalise on the changes to supercomputing architecture and make fundamental changes in the way they run.

How can CFD thrive?

Another problem facing CFD is the sheer amount of parallelisation; utilising this efficiently goes beyond hierarchical parallelisation or optimisation. The core CFD algorithms must be updated in order to avoid certain communication patterns and obtain the highest possible performance. Global communications often creep into CFD algorithms via certain additional transport equations or through specialist routines (e.g. for adaptive meshing). They are also a fundamental part of the linear equation-system solvers which are at the heart of CFD. Global communication is caused by, for example, finding the mean value of a flow variable or computing a residual – to continue the metaphor, it's like trying to find which of your 20,000 mice has the longest tail.

As the demand for higher accuracy in CFD increases, more pressure is placed on these creaking algorithms, via higher-order discretisation schemes and closer coupling of the equation systems. Additionally, as more flexibility is demanded via mesh refinement, complex modelling capabilities, overlapping meshes, etc. – it becomes difficult to maintain a scalable code. The codes that thrive will be those that can offer these capabilities without sacrificing performance.

Work is currently being undertaken at the University of Southampton, in conjunction with the Maritime Institute Netherlands (MARIN) to improve the scalability of the core algorithms. Particularly this focuses on scaling the linear solvers to a many-core environment and investigating dynamic balancing for dark silicon [3]. Other developments for scalable CFD tackle such areas as:

- Parallel methods for grid generation: ensuring that reading or creating mesh data does not become a bottleneck to the solver.
- Scalable post-processing: using *Big Data* analytics to create useful results from millions of cells in a computationally efficient way.
- Scalable discretisation techniques: especially concerning sliding or overset mesh technology.
- Parallel time-stepping: allowing the time domain to be parallelised, improving scalability by partitioning the simulation in four dimensions.

New thinking is required in the development of CFD to obtain a harmony between hardware, software and hydrodynamics. Whether the codes are commercial, open-source or in-house; utilising super-computers or desktop workstations; for one-off high-resolution simulations or batch optimisation – they must adapt to stay ahead of the game. *NA*

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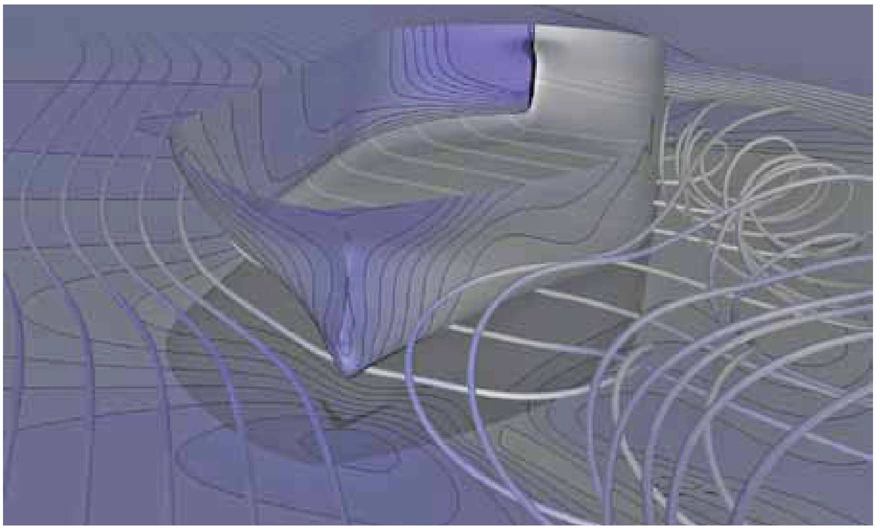
Figure 5: Advanced manoeuvering simulations in ReFRESCO. (marin.nl)



Simulated waves bring real surprises

Hull form optimisation based on computational fluid dynamics traditionally benchmarks against performance in calm sea states. A new approach from Foreship introduces real sea conditions into the equation

Demanding targets through the ever greater clamour for cleaner, more efficient ships are driving designers to develop their ideas in ship design technology and methodology.

It is in this context that Finnish design and engineering company Foreship has improved the use of computational fluid dynamics (CFD) moving from the traditional calm sea performance benchmarks to the more realistic approach that identifies actual sea states in the design process. And that shift has brought some surprises says Foreship.

"Cruise ship hull designs have become so optimised in recent years that true innovation has demanded fresh thinking because the hard targets to improve performance keep coming," says Mattias Jörgensen, Foreship Vice President Business Development. "Generation to generation, cruise ships have made massive strides in terms of energy efficiency, but forward-looking owners continue to want more."

In June Foreship disclosed that the 'fresh thinking' Jörgensen is referring to had found commercial form, as it began talking openly about a new approach to CFD which factored real sea states into hull form optimisation.

Despite quickening processing speeds and improved accuracy, the CFD modelling used in commercial ship design has, to date, only considered calm seas. Modelling the real conditions faced by ships at sea for design purposes has largely been an academic endeavour.

"Discussions with cruise ship owners concerning how to optimise hull forms in real conditions have been ongoing for around five years, but it has taken time to develop the practical tools," explains Janne Niittymäki, Foreship Head of Hydrodynamics. "A lot has happened in the field of CFD over those years, and it has become practical to look at frictional resistance below the water in a way that considers the complexities of wave motions."

"Actual conditions at sea are very rarely completely calm, and the optimal hull form for real operational conditions is likely to differ significantly from one optimised for calm seas," says Jörgensen.

The optimal hull form for a real operational profile is likely to be very different from the optimal hull for calm seas, says Foreship's VP Business Development Mattias Jörgensen.

"Our initial work was not client-specific, and looked at the methodology of CFD simulation based on real conditions. We created simulations including average wave heights that remain constant throughout the cycle of the ship and along the entire length of the hull form. The density of the grid used in the modelling was increased when compared to a traditional simulation."

Foreship brought its expertise to bear on advancing the capability of OpenFOAM, the open source CFD software package, developing the coding required for hull optimisation and graphical interfaces that simulate real conditions. Inputs include the baseline 3D hull form and any possible restrictions, with normal operational conditions based on expected wave heights, wave periods and speed range.

The typical work scope for the new RANS-CFD optimisation programme considers the impact of head waves and following waves in one sea state (with an average 1.4m wave height) and three ship speeds. The analysis determines the differences in bare hull resistance in waves and in calm water to assess hull form variants for best performance. In addition, the effect of the hull form selected on ship motions and wave impacts (slamming forces) can be determined.

While self-evidently desirable, the full significance of the change in approach only became clear after the new Foreship RANS-CFD based method was deployed in design work for one of the Finnish company's leading cruise ship customers.

"After a specific request from a client, we entered a more intensive phase around 18 months ago as part of a cruise ship newbuilding project, although I should emphasise that the same approach is appropriate for any type of ship," says Niittymäki.

The project in question looked to compare the performance of a bulbous bow versus a vertical stem bow on board a cruise vessel of around 300m in length optimised for 18kn. The beam, draught, block coefficient and submerged hull length were constant.

"It is received wisdom that the bulbous bow is the optimal solution in calm water, but above a certain threshold condition (wave height and period) the vertical stem becomes the optimal solution," says Niittymäki. "But what is the threshold?"

Using the new method, the simulations showed that in calm water the bulbous bow could be considered a marginally 'better' solution in speeds ranging between 14-18knots; but that at 22knots the vertical stem was demonstrably better, achieving 2.7% less resistance.

However, in conditions simulated to include head waves (Hs = 1.75, Tp = 8s), modelled in intervals of 20s in calm seas and 25s in waves, the vertical stem achieved an improvement in hull resistance of above 2% even in small regular head waves across 14, 18 and 22knots test speeds. The differences in ship motions were considered insignificant in the context of resistance.

"When the first estimates came through, I have to say that I did not believe them," says Niittymäki. "I believed that the vertical stem would be seen to be the better option at some point, but not at such low wave heights. The resistance in waves was shown to be clearly better across the whole speed range in the case of the vertical stem version. We knew that even small waves might affect how the optimal hull form was decided on, but it is only now that we have the new methodology that we can measure precisely what the effect will be."

Using Foreship's RANS-CFD method at an early stage will confer more freedom for modification than would be the case after model testing. However, Niittymäki emphasises that the benefits translate directly into a language shipowners will also find persuasive: "Real fuel consumption gains will be very significant in the practical case we have worked on and other hull optimisation improvements will achieve the same outcome," he says.

For the cruise ship industry, a 2% margin of improvement in terms of frictional resistance is a 'big deal'. However, Niittymäki adds: "Naturally, this would not be so significant for other vessel types, but the point is that the methodology is in place to simulate other factors, such as seakeeping or slamming, which may be the leading consideration for other owners. The same CFD methodology would be applied to evaluate the optimum hull form at the earliest possible stage."

In the normal course of events, hull form optimisation is verified by model testing at a later stage of design. While this will remain the case, Niittymäki emphasises that one of the benefits of the new methodology is that no further modifications would be expected.

In addition, CFD simulation is repeatable in a way that model testing is not, meaning that small adjustments can be easily modelled. "The simulation can be run quite quickly; part of the development plan for this methodology was that it would need to be commercially applicable."

Niittymäki stresses that the new methodology does not replace model testing as such. Developing the existing model to take account of varying sea states and oblique wave motions is attainable, if "a little more time-consuming", he says, because the current simulation runs a 'half hull-form model'. Simulating speed/power performance of potential hull forms would not be advisable, because speed ranges of 10-25knots need to be considered in 1knots intervals, implying an impractical number of simulations.

For the moment, however, Jörgensen believes attention should focus on what has already been achieved. "It was truly a surprise to our hydrodynamics specialists how close to calm seas conditions the vertical stem bow becomes preferable to the bulbous bow," he says. "This new approach to CFD opens up significant new potential for commercial ship design." *NA*

Oshima develops LNG bulker

As new environmental legislation continues to develop, and with an urgent need for owners to save money through greater fuel efficiency, new designs for ships using alternative fuels are appearing. Sandra Speares investigates

A new environmentally friendly bulk carrier design has been developed by Japan's Oshima Shipbuilding Company which recently received approval in principle for a new LNG-fuelled Kamsarmax bulk carrier from classification society DNV GL.

The new design complies not only with DNV GL class rules, but with all current and upcoming regulations, including the new emission control regulations and the draft IGF Code for fuel with a low flashpoint.

As regulations on harmful ship emissions such as sulphur become stricter, reducing SOx, NOx, CO_2 and particulate matter is at the top of the agenda for many players in the maritime industry. As a result, shipowners and operators are increasingly looking into the use of alternative fuels to ensure compliance for their fleet, now and in the future.

"LNG is emerging in a number of ship sectors and has great potential. We were very pleased to work on this innovative design with Oshima. It offers customers a flexible, safe, future-proof solution and the opportunity to almost eliminate SOx emissions and particulate matter, cut NOx by 80% with EGR (Exhaust Gas Recirculation) and reduces CO_2," says Morten Løvstad, DNV GL bulk carrier business director.

As space on deck is limited on a bulk carrier, the design includes changing the ship's superstructure to a U-shape that can accommodate the LNG tank in its centre. This approach allows the accommodation deck house to be completely separated from the LNG storage tank and scalability in terms of the amount of LNG storage onboard. Meanwhile, a tank cover adds an additional safety barrier and ensures compliance with the draft IGF Code. The bunkering stations for LNG, heavy fuel oil (HFO) and marine diesel oil are located at the side of the accommodation deck house, DNV GL explains.

Space restrictions on Oshima's Kamsarmax bulk carrier design puts the vessel's LNG tank behind the accommodation block

Tatsurou Iwashita, director and general manager of the design department at Oshima, points out: "One of the main factors for shipowners and operators considering the use of LNG as a ship fuel is the space required to store LNG on board. But as a result of our changes to the superstructure, our design does not reduce the vessel's cargo capacity. Combined with its dual fuel capabilities, this should make the design very attractive for charterers, especially for trade routes where the LNG fuel price is competitive to HFO and substantially cheaper than marine gas oil (MGO)."

The Kamsarmax vessel is designed for dual fuel operation, using both LNG and HFO to power the main engine, the generators and the boiler. The LNG handling system for receiving agreement in principal was supported by Mitsubishi Heavy Industries. Oshima's latest Panamax/Kamsarmax hull design provided the basis for the vessel's shape. This design has proved successful, and its fuel performance is well documented, providing the experts with important operational data they could use to adapt the design to LNG operation, DNV GL says.

The vessel's parameters are also based on data generated in a DNV GL feasibility study from 2014 that examined the use of LNG in a trade route between Europe and North America from a technological and

economic perspective. "Taking all relevant factors into account, we found that a LNG-fuelled Kamsarmax bulk carrier, which only uses LNG in Emission Control Areas, would require 500–700m^3 of LNG and one bunkering operation for a round trip between Europe and North America," says Løvstad. If it were powered with LNG for the entire voyage, it would require 2,000–2,500m^3 of LNG.

Oshima Shipbuilding and DNV GL had already co-operated on several innovative bulk carrier concept designs in the past, and Oshima already had a Kamsarmax design which was highly optimised from a hull resistance and cargo capacity point of view, and so the two parties decided to join forces again in order to develop a state-of-the art LNG fuelled Kamsarmax design.

A joint development project was started with the objective to develop a commercially attractive and flexible design that can accommodate any LNG volume requirement up to about 2,500m^3 (in case of an IMO type C-tank) and about 3,000m^3 (in case of an IMO type B-tank) as well as being able to accommodate both LNG type C and type B tanks at the same dedicated deck space. This means it is possible to keep the same cargo capacity as a conventional oil fuelled bulk carrier. The most significant modifications are done on the superstructure and in the engine room, DNV GL explains.

On a bulk carrier, the available space on deck is limited and therefore major modifications were required in the superstructure in order to accommodate the LNG tank(s) with the main priority to keep the existing vessel cargo capacity. The LNG tank(s) (either IMO type C or B, depending on the required LNG volume) are protected by a steel cover forming a box which is part of the hull structure and provides additional safety in case of dropped objects, gas leakage or fire. This arrangement allows the accommodation deck house to be completely separated from the LNG storage tank. The tank cover also adds an additional safety barrier and offers full compliance with the draft IGF Code.

The bunkering stations for LNG, HFO and marine diesel oil are located at the side of the accommodation deck house. Main and auxiliary engines are dual fuel as well as the boiler. From the storage tank, LNG flows to the gas preparation room which is located at the port side of the vessel offering additional safety with regards to the position of the free fall lifeboat. Following the gas preparation room, gas is fed to the dual fuel engines for combustion.

The vessel has been designed on an existing, already successful hull design, meaning that the vessel fuel performance is already well documented. The vessel can be ordered as gas fuelled or gas ready. By using the DNV GL GAS READY notation the vessel is prepared for future retrofit of LNG equipment.

This gives the flexibility for the owner to postpone a major part of the additional CAPEX, but still having the flexibility to install the LNG tank and gas fuel supply system at a later stage without incurring significantly extra costs compared to doing such installation during vessel construction. Further, the innovative accommodation arrangement makes retrofit installation easier than for a conventional design, and will have a competitive advantage in the future.

As far as compliance with existing regulations are concerned, according to Alex Chiotopoulos of DNV GL, owners choose which engine manufacturer they want, for example Wärtsilä or MAN, as each manufacturer has its own technical solutions in order to comply, for example with US environmental requirements. The main advantage he says is that the performance of the vessel is maintained while large quantities of gas can be carried.

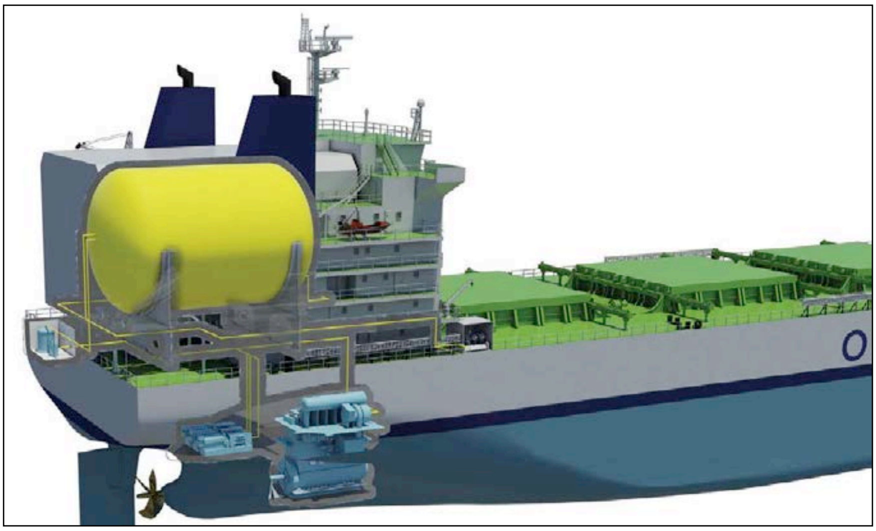
Meanwhile Deltamarin has received an order from Vulica Shipping for its B.Delta68 SUL (self-unloading) vessels design. The order for the two bulk carriers was placed with the Chinese Jiangsu Hantong Ship Heavy Industry.

Deltamarin's contract with Hantong shipyard covers design approval, procurement handling and site assistance. The contract value is about €3 million (US$3.3million) and the estimated contract period is 10 months. Delivery of the vessels is planned to take place before July 2017.

The B.Delta68 SUL is a Panamax-sized self-unloading bulk carrier featuring a state-of-the-art, fuel efficient and environmentally friendly design. The vessel design is developed by Deltamarin and tailor-made for the customer's special purposes. The ships will comply with the most stringent environmental regulations, Deltamarin says.

The design is based on the fully tested hull of the larger B.Delta82, but with shallower draught. The overall length of the vessel is 229m, 32m across the beam with a maximum draught of 12.8m. The guaranteed service speed shall be at least 13.5knots. According to Konstantinos Fakiolas, sales director at Deltamarin: "Once launched the vessel will be the most efficient and modern SUL bulk carriers on a worldwide scale".

The B.Delta Series comprises a design family with capacities ranging from 25,000dwt up to 210,000dwt. The designs cover both standardised industry sizes



A cutaway view of the LNG fuel tank

(handy, handymax, ultramax, kamsarmax, newcastlemax) and cargo-volume sized ships for more niche markets. As a result of the flexibility of the design, the ships can be tailor-fitted for various cargo types, ice-class notations, Laker versions, self-unloaders and other specialised trades. The B.Delta designs offer advantages like low fuel oil consumption, low emissions, EEDI compliance, high deadweight intake and optimised lightweight particulars.

The current orderbook of the B.Delta family includes 121 ships, mostly of the B.Delta37 and B.Delta43 types, but also self-unloader and Laker ships. B.Delta derivatives, such as chemical tankers, are also under construction in China.

In total, already 40 B.Delta ships have been delivered from six different shipyards in China to nine shipowners.

Meanwhile Turkey-based Ecoships recently included a customised version of the Six Sigma DMAIC as a means of optimising the energy efficiency of ships under its management.

The company says fuel efficiency is 15% greater with much reduced emissions of CO_2, NOx and SOx emissions.

One vessel it has under management is the 25,000dwt bulk carrier *Bulk Rose* which was delivered from Turkey's Cicek Shipyard in 2011 which was initially consuming 840g/dwt of fuel per day. It now consumes 750g/dwt/day.

As well as being designed to operate efficiently through the improved hull design, the Kamsarmax vessel will reduce emissions by burning LNG in Emission Control Areas

Liquefaction

One of the main hazards for bulk carriers is cargo liquefaction, and DNV GL has issued guidelines to address the problem.

As the classification society has pointed out, the time between liquefaction being detected and the possible capsize of the vessel is short, which allows little time to evacuate the crew, often with tragic consequences

Accidents also follow a geographical pattern involving ships visiting the same ports, the class society suggests.

Recent casualties include the Gearbulk-owned *Bulk Jupiter* which sank in December with the loss of all but one of its 19-man crew.

Commenting after the tragedy the American Club said: "The International Maritime Solid Bulk Cargoes Code (IMSBC) lists bauxite as a group C cargo, i.e. one not known to liquefy or possess a chemical hazard. However, this categorisation only applies to bauxite cargoes which have a moisture content between 0% and 10% and which consist of 70% to 90% of lumps with a size between 2.5mm and 500mm, and 10% to 30% of powder."

However, the club said: "Where any of the properties listed in Appendix 1 of the Code for such cargoes are not fulfilled – for example where heavy local rainfall has created an excessive moisture content of a shipment to be loaded – then the requirements of section 1.3 of the IMSBC Code for cargoes which do not fall within the above specifications should be followed."

The main risk represented by liquefaction is that the cargo may shift, DNV GL explains. Its report suggests that "nickel ore is arguably the most dangerous of all bulk cargoes, suspected of claiming the lives of 81 seafarers since 2010."

"Bauxite is an aluminium ore and is listed as a Group C cargo in the IMSBC Code. However, it should be noted that in some cases the ore is sieved before shipping to remove large lumps. Sieving involves using high-pressure water to force the ore into rotary sieves. In addition to increasing the portion of fines, this adds water to the cargo. Both these factors increase the risk of liquefaction for bauxite too."

The guideline focuses on what mitigating actions may be taken at the design stage, as well as highlighting conditions that may call for independent, third-party tests to be conducted to check and report the actual cargo condition prior to loading.

The DMAIC technique was used to identify energy efficient practices including trim optimisation and weather routing software, *Bulk Rose* was fitted with a shaft generator and the company estimates that energy efficiency has been improved by 11%.

Six Sigma DMAIC, a set of techniques used to Define, Measure, Analyse, Improve and Control operational performance and processes, was first developed by Motorola in 1986.

Another recent development has been Green Dolphin 84S – a concept developed by the Shanghai Merchant Ship Design & Research Institute (SDARI), with support from DNV GL. "The main objective of DNV GL's assistance during the development of the Green Dolphin 84S was to help create confidence in the concept design proposed by SDARI for a wide-beam, shallow draught 84,000dwt vessel. DNV GL's scope included developing an expected operating profile, analysing the hydrodynamic performance of the hull shape, calculating the propulsion efficiency and estimating the fuel oil consumption," the class society explains.

The operating profile was determined based on the trade volume distribution for this bulk carrier segment – looking into trade volumes, voyage distances and the number of voyages for the various cargoes. Sample trades were studied to estimate average voyage speeds and data on draft limitations for a country/port and the relevant cargo-lifting restrictions were taken into consideration when developing the operating profile for the concept design.

SDARI had developed a candidate design and W Marine asked DNV GL to assess the hull with regard to resistance and wake. The assessment focused on the design point in addition to four main operating points from the operating profile. The detailed flow characteristics were carefully studied for possible improvement potential.

"The assessment concluded that the bare hull resistance and wake properties were as expected for a well optimised design with the required main dimensions and fullness, i.e. there was little or no room for improvement of the hull received from SDARI. It was noted that it might be worthwhile to implement trim guidance at light cargo drafts due to the typical transom flow behaviour," according to DNV GL.

The class society says the wake is considered good and again representative of a mature and fuel efficient design, but the high block design puts limits on the wake quality and the design may benefit from a wake equalising duct or propulsion improvement device with a similar effect. W Marine hired DNV GL to assist in the further assessment of an optimal propulsion improvement device that would best match the design propulsion characteristics.

Several main engine and propeller options were also assessed in terms of propulsion efficiency to ensure a lowest possible fuel oil consumption.

Dr Olav Rognebakke, who has been in charge of DNV GL's team, gave credit to the work done by SDARI when he stated: "It is interesting to note that our scope of work has shifted from pure optimisation to verification," adding: "It's encouraging to see that our work has helped to reduce some of the risks involved in ordering a new design and that this design has already been ordered!" *NA*

Norwegians keep Eastern European yards afloat

Newbuilding and repair activity in Eastern Europe has been continuing although sanctions have affected some regions, writes Sandra Speares

Ark Germania had its new scrubber unit fitted at Remontowa in Poland

The repair activity at yards in Croatia, Romania and Bulgaria is fluctuating at moderate activity levels according to Loizos Isaias, of DNV GL.

However: "The repair activity in Ukraine has been significantly reduced due to the political situation in the country," he adds.

Newbuilding yards are mainly found in Turkey, Italy, Romania, Croatia and Ukraine.

Yards are busy with the construction of various small-size specialised vessels, mainly for Norwegian owners, but also with the construction of hulls intended for completion at Norwegian yards, Isaias explains.

Since 2002, huge investments supported by the Turkish Government have been made in establishing new shipyards. Idle capacity adds potential to the Turkish newbuilding industry: there are several yards available, flexible to retain business (open for both newbuilding and ship repair), on the small to medium scale and mainly specialised in short sea shipping sized vessels.

In Romania the main newbuilding yards are part of groups located in Norway like Vard, or in the Netherlands (Damen) and Korea's Daewoo Shipbuilding and Marine Engineering (DSME) facility. Larger vessels are being built in DSME's Mangalia shipyard in Romania.

The Croatian shipyards were state-owned, but now all yards are being privatised says Isaias. New owners have to continue with the core business of shipbuilding as part of the privatisation agreement for a period of three-five years. "Their weaknesses, such as technological lagging, lower productivity, inadequate structure of skilled workers, low financial potential are the main obstacles which should be resolved during the process of restructuring."

In Ukraine the majority of the yards are idle with no business prospects at the moment, due to the political situation in the country, he notes.

From 1 January, 2015 new EU legislation came into effect limiting the sulphur content of the fuel used by shipping lines operating within Emissions Control Areas of the North Sea, Baltic Sea and the English Channel.

Shipping lines' compliance to the directive can be achieved through several solutions, including changing to low sulphur Marine Gas Oil, which has been cited as being approximately 50% more expensive than heavy fuel oil; installing purification systems like scrubbers or investment in new vessels running on alternative fuels.

By the end of May 2015, Gdansk-based Remontowa had installed scrubber systems on 30 vessels for various owners for car and passenger ferries, cargo ro-ros, gas tankers, and multipurpose cargo vessels.

Danish owner DFDS Seaways is investing over €100 million (US$109.25 million) in the installation of scrubber systems on 21 of its cargo ro-ros. So far 15 of them have the systems already installed. Most of these ships received their scrubber installations at Remontowa.

According to the company "No scrubber installation job is the same. Even if the same system is used, the installation differs from one ship to another.

"Remontowa has gained experience in installation of scrubber systems of various designs from various manufacturers, such as EcoSpray, Alfa Laval, AEC Maritime or Wärtsilä."

Installation of the scrubber is not limited to placing an actual scrubber into a (usually modified) funnel stack. There are many related works, partial modification to some structures on the ship and installation of new accompanying systems, the company added.

Recently, yet another DFDS Seaways ro-ro with scrubber in its modified funnel left the Gdansk based yard, the *Ark Germania* which is 196.3m long, 34.2m wide, with a 5.5m draught and with 12,000dwt capacity, built in 2004 at German yard PS Werften Stralsund.

The scrubber system on *Ark Germania* was installed in line with a similar engineering design done on a sister vessel – *Ark Dania* in March 2015.

Both ships are designed and built to conform to NATO requirements, to cope with possible transport of military equipment, mainly various military vehicles. When not hired by German or Danish military, the ships are trading commercially.

The scope of repair works on both vessels has been roughly similar. They included shaft line measurements and rudders, replacement of stern shaft seals, minor repairs to stern ramps (which are designed with segments, so that the ship and its stern ramp may fit to both wider and narrower shore ramps.

Since May 2015, *Ark Germania* has been operating on the Esbjerg – Immingham route (six loops weekly). For *Ark Germania* and *Ark Dania* the supplier of scrubber systems chosen by the owner was ME Production / Marine Exhaust Technology.

In their scrubber SOx is washed out of the exhaust gas by injecting sodium carbonate the reacting agent in the process water. The scrubber unit design is always customised according to the individual vessel and the available space on board.

Sodium Carbonate is injected in the process water as the reacting agent to remove SOx in the exhaust gas. The Na_2CO_3 agent is supplied from the dosing unit.

The supply of process water for the scrubber unit is taken from the process tank. The process water is also returned to this tank. Fresh water is added continuously and waste water is taken out for waste water treatment.

The cooling system is based on seawater being pumped into a heat exchanger and from there back to the sea in a closed system without any connection to the internal process water flows. The process water is continuously cooled for an optimised scrubbing process.

Waste water from the process tank is treated to separate sludge content and waste water. Sludge content is sent to the ship's normal sludge tank and waste water is then again cleaned to a quality level that allows discharge of most of the water. The rest of the waste water is sent to a holding tank for disposal in port.

There have been as many as 40 scrubber systems contracted for installation at Remontowa in 2014-2015.

Meanwhile, AS Tallink Grupp and Meyer Turku Oy signed a contract recently for the construction of an LNG - powered fast ferry for Tallinn-Helsinki route shuttle operations. The dual fuel ship will be about 212m in length with a passenger capacity of 2,800. The fast ferry will cost around €230 million (US$251.13 million) and will be built at Meyer Turku shipyard for delivery in the beginning of 2017.

The new ship uses LNG as fuel and will comply with the new and stricter emission regulations for the ECA areas including the Baltic Sea. The 49,000gt ship will have a service speed of 27knots with a hull form that minimises the flow resistance and ensures that the ship operates well in ice conditions.

AS Tallink Grupp CEO, Janek Stalmeister says that Tallink wants to develop sea travel and to revolutionise business and this project forms part of that plan. "We have brought a new understanding to the fast ferry services with the Shuttle concept and now the time is right to take the next step. We have learned from our own experience, listened to our customers and experts and we are now very excited about the end result", he added.

"Meyer Turku is very happy to continue the long and good tradition of building ferries for Tallink and with our new and advanced LNG propulsion plant we are lifting this partnership to the next technological level," commented Jan Meyer, CEO of Meyer Turku Oy.

Russian LNG-Gorskaya has signed a contract with shipbuilder United Shipbuilding Corporation (USC) for the construction of Russia's first three LNG bunkering tankers.

The three tankers with capacity of 7,300m^3 each are scheduled to be delivered in 2017.

Dutch gas tanker shipowner Anthony Veder has also signed an agreement with Finnish natural gas importer Gasum for construction and a long term charter of an 18,000m^3 LNG carrier.

The new ICE Class 1A Super LNG carrier will be built at German shipyard Neptun Werft and delivered in the last quarter of 2017 and will deliver LNG to the Röyttä terminal in Tornio in the Baltic Sea, the vessel will have to have the highest ice class notation for the vessel to trade in the extreme weather conditions. The vessel will also use the LNG boil-off gas for its main and auxiliary engines.

VARD meanwhile has, through its subsidiary Seaonics, acquired ICD Software, a leading provider of automation and control system software for the offshore and marine sectors.

Established in 2011 and 51% controlled by VARD, Seaonics delivers winches, cranes and handling equipment to the offshore and maritime sector. The company has developed cranes for critical offshore lifting operations up to 250tonnes. Prior to the transaction, Seaonics employed 50 employees in Norway and a subsidiary in Poland.

ICD Software is specialised in the development of automation software and control systems, and employs 63, half of whom are based in Norway and the remainder in two subsidiaries in Poland and Estonia.

Through the acquisition of ICD Software and its subsidiaries, Seaonics is able to expand its business in deck handling equipment and automation technology, the company says.

VARD Executive Vice President for Equipment and Solutions and Chairman of Seaonics, Stig Bjørkedal, commented, "This acquisition is a catalyst for growth and development of Seaonics, and an important step for VARD in strengthening our equipment and solutions portfolio. The integration of in-house developed automation and control system software enables us to offer a complete complex product delivery to the customer." *NA*

The Remontowa yard in Poland has been busy fitting scrubbers to 30 ships

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Ice class!

In 2014 the Krylov State Research Centre completed construction of its new ice basin. The purpose of the facility is to develop the capabilities of the institute taking advantage of previous experience in model investigations

After more than 25 years in operation the Krylov State Research Centre's (KSRC) first ice model tank commissioned back in 1985 could no longer satisfy the research aspirations of ice scientists and engineers.

In view of these considerations and the need to perform a range of investigations in the immediate future to support industrial development of the Russian Arctic it was necessary that a new modern ice basin be built [1]. Appropriate estimations and justifications were done to support the new ice basin project with the work to build the new tank starting in 2012 with completion of the facility having occurred last year.

The Krylov Centre scientists and engineers have elaborated on the concept of the new ice basin [1]. Table 1 summarises the main design particulars of the basin defined in accordance with this concept and compares it with the main data of the older ice tank.

The newly built ice basin has the capability to make two fundamentally different types of model ice for the more accurate simulation of operating environments for various ship types and marine structures, which no other existing ice basins can do.

One of these types is a so-called columnar ice, which is produced using the method suggested by the Arctic and Antarctic Research Institute [2]. This method was instrumental in the development of the first ice tank in the last century. However, many scientists around the world continued to further investigate this issue, and Finnish specialists have invented a fine-grained ice modelling technology.

This technology enables ice basins to double or triple their ice test productivity. KSRC's ice basin is now able to apply this technology along with the more traditional Russian model ice technology to carry out a broad spectrum of research studies (Figure 1).

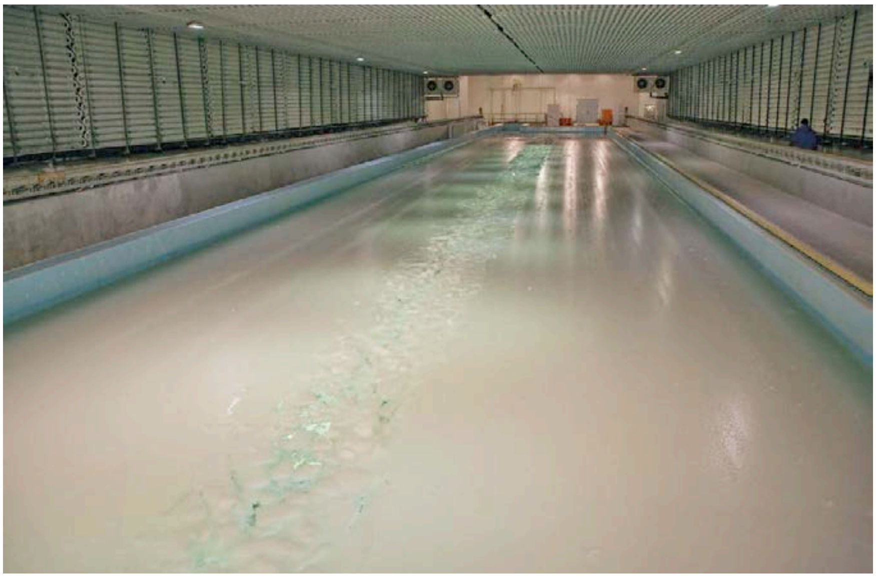


Figure 1. Fine-grained ice sheet, view of the Krylov new ice basin

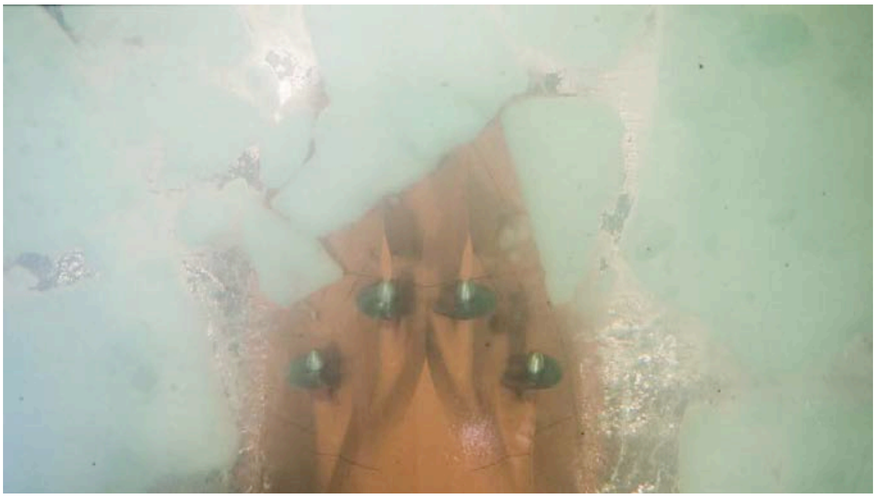


Figure 2. Visualisation of propeller and ice interaction processes

A significant development in the new basin is the optimisation of the water supply to the auxiliary (service) carriage to avoid any ice in the water supply hose or spray system during the model ice making process [3]. To solve this problem the ice laboratory engineers suggested a channel that should run outside and parallel to the basin bowl and be connected to the main water volume of the basin by a system of pipelines. In this way the ice making process is uninterrupted when the temperature in the room is sufficiently low.

Special design efforts have been taken to provide the best possible visualisation of ice/structure interaction processes in this new ice test facility (Figure.2). For this purpose the basin bottom has large view ports to allow observation, video and photography from the bottom. In addition, two observation tunnels are provided on

Characteristics	Old	New
Basin length including bay, m	50	102
Ice sheet length, m	35	80
Basin width, m	6	10
Basin depth, m (in brackets – depth of 20% length section at the basin end)	2 (3)	2 (4.6)
Ice thickness range, mm	10 – 100	10 – 130
Speed of towing carriage, m/s	0.005 – 1.0	0.0005 – 1.5
Average time to make one ice sheet, days	2	1-2

Table 1: New and Old Ice Basins of the Krylov State Research Centre

Figure 3. An icebreaker model test at KSRC

both sides of the basin. One of the tunnels enables observers to view a running test model from top, while the other one makes it possible to have a side view of models below the water level.

A wide range of model tests can be staged in the new ice basin to investigate various ships and marine structures. For this purpose new ice-making and test techniques have been developed in an effort to raise the productivity of experiments.

One of the routine types of experimental studies conducted in ice tanks is ice resistance tests for icebreakers and ice-class vessels providing initial data for further refinement of hull lines (Figure 3).

A major advantage of the newly built KSRC ice basin is a marked improvement in productivity of some tests which are two to four times higher compared to many other existing ice tanks. This level of productivity is achieved because of the long lengths of ice sheets which can now be frozen in the basin, as well as more efficient utilisation of the ice sheet width when experiments are conducted in parallel channels using special reinforcements, so-called "ice scratches". Moreover, KSRC's researchers have worked out a technology, which is now under verification, for making an ice sheet with two different thicknesses.

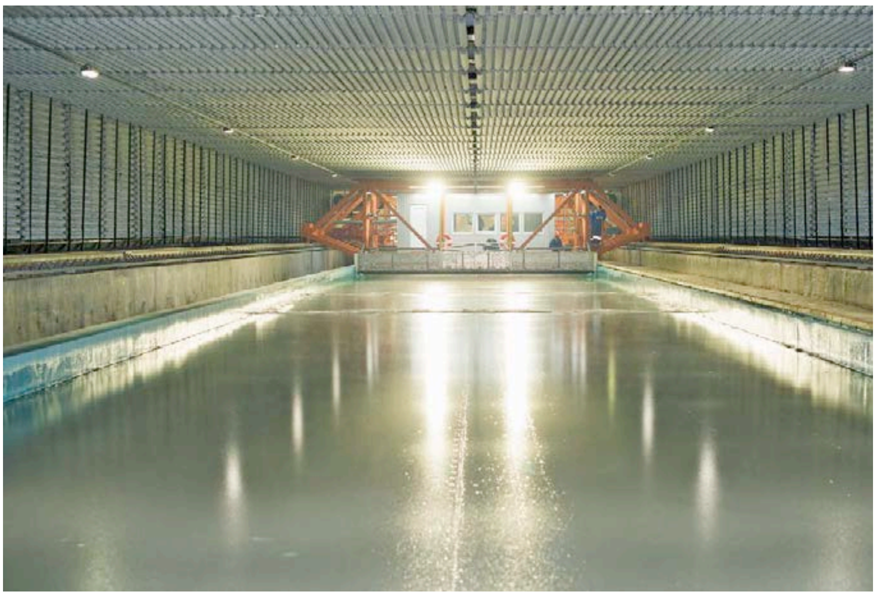
The basin depth was specified to be 2m over 80% of its length. This depth enables efficient visualisation of ice interaction with submerged parts of models and effective use of the false bottom during various experiments on marine structures. The basin depth increases to 4m at the end section covering 20% of its total length for experiments on models with mooring systems.

In recent years we have witnessed rapid progress in ice technologies giving rise to a new field of research studies in ice tanks focusing on so-called ice management techniques, i.e. special icebreaking operations intended to relieve ice loads on marine structures. The Krylov Centre researchers have developed a system for physical modelling of ice management operations. For this purpose special equipment was developed to be installed on the ship model under study for recording physical values, fixing model position coordinates as well as the execution of real-time control functions.

It should be noted that the Krylov ice basin incorporates a range of other novel features intended for refining ice navigation tactics including interactions with icebreakers, offloading terminals, etc. Another merit of the newly built ice facility is the capability of its service carriage usually intended for seeding and removing ice. The service carriage of the basin can be additionally outfitted with measuring instrumentation and used as a platform for a wide range of non-standard experiments.

For the investigations of ship manoeuvrability in ice the main towing carriage is also equipped with a Planar Motion Mechanism (PMM) running normal to the basin axis according to the prescribed law. In addition, PMM can be used to impart

Figure 4. Service carriage of Krylov's new ice basin



a prescribed angular speed to a ship model. It therefore enables measurement of ice forces and moments acting on a model under curvilinear motion.

In the testing of floating and fixed marine structures PMM is also used to test floating and fixed marine structures in order to model changes in ice drift directions, this allows for the examination of the ice load effects and ice/structure interaction. The main towing carriage was designed to meet rather tough requirements to maintain a specified speed range of 0.01 to 1.5m/s.

Other common types of experiments in ice basins are the tests conducted to determine global ice loads on marine structures, sometimes including bottom effects; study and optimisation of ice protection systems and elements. A new design of the towing carriage incorporating a number of lifting panels and rotating gears makes it possible to save time and power during performance of such experiments.

The newly built ice basin is capable of modelling and reproducing the following ice conditions:

- continuous level fast and drifting ice;
- brash ice, broken ice, ice floes;
- ice ridges, ice hillocks, rubble ice;
- simulation of ice compression processes;
- fresh and old channels in ice.

Based on the wealth of previous ice research experience, Krylov's scientists have developed up-to-date technologies for modelling ice ridges with a specified thickness of consolidated layers positioned at any desired angle with respect to model heading or ice drift direction. Apart from ice ridges it is also possible to model rubble ice fields and channels filled up with brash ice in the new ice basin. *NA*

AUTHORS

Oleg Timofeev, Deputy Director General, Kirill Sazonov, Head of laboratory of ice engineering and Aleksey Dobrodeev, Head of ice research at the Krylov Institute.

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Managing the shipbuilding process

Construction management is expected to provide construction data and information to understand current state and to make decisions for managing QCD (quality, cost and delivery) at construction shop floors in shipbuilding.

Visualising the vessel construction itself is a key approach to finding problems in process management. In order to visualise the process an advanced construction process monitoring system has been designed to monitor construction modules, workers and several operations (i.e., welding operations, grinding operations and so on.) using advanced ICT including sensing and image processing technologies.

The intensification of the global economic slowdown and the increase in the gap between tonnage supply and demand has led to an aggravation of competition in the future international shipbuilding market.

In this serious situation, it is essential to improve the competitiveness of QCD (Quality, Cost and Delivery) for the surviving shipbuilding industry. In order to improve this competitiveness, there is no disagreement that the establishment and sophistication of a total construction management system in the shipbuilding process is necessary.

One method that is being used to increase shipyard competitiveness is to obtain enough task records from which they can extract task result information that will help them to better perceive and understand the current task state on construction shop floors.

Collection of crucial data for construction management is necessary in order to develop a well-organised construction management system.

Basically, material handling, assembly operations, time management and construction projects are managed by using these data. However, the reality is that very long time durations and large costs are necessary to obtain this data because it is currently collected manually in shipyards. In order to improve the efficiency of the construction system, it is essential to develop an effective, intelligent and economical way to collect all of these important data and design a feasible way to analyse and calculate this crucial data to help effective construction management to be as automated as possible.

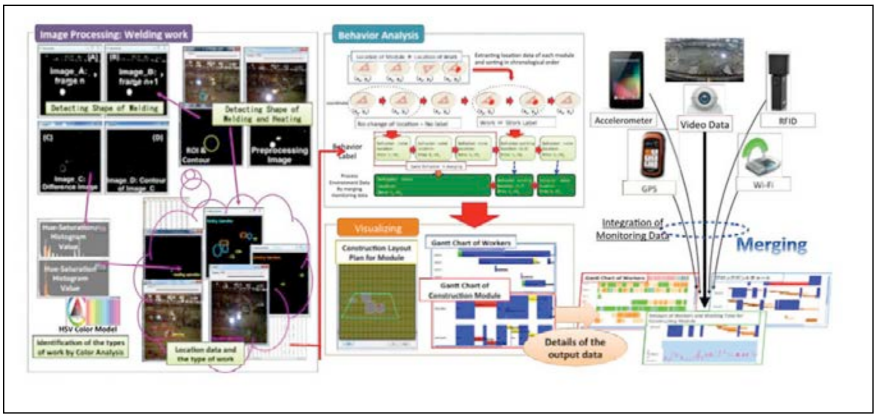

Figure 1: Functions of the Construction Process Monitoring System include Collecting Monitoring Data (Image-Processed Data and Sensor Data) and functions for Generating and Visualising Operation Data

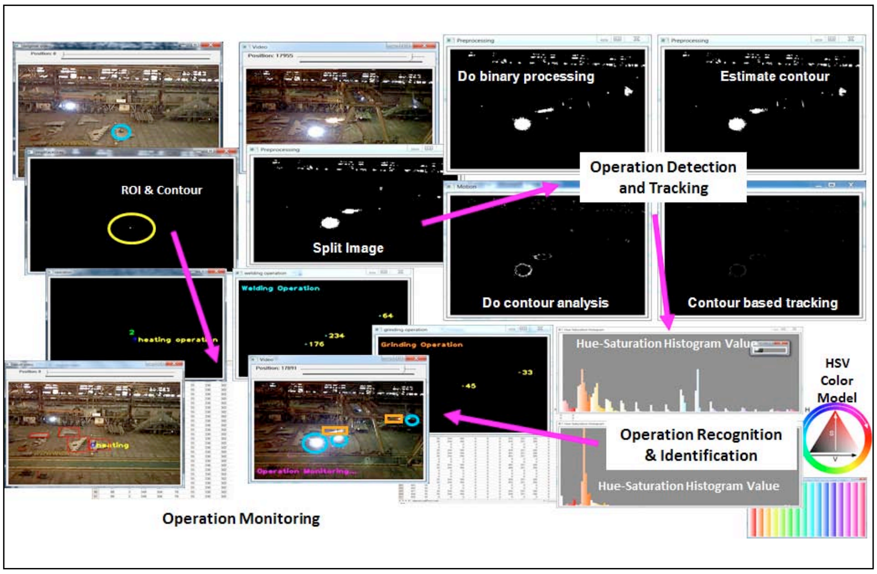

Figure 2: Video Image Processing for Welding, Grinding, and Heating Operations

Functions of a monitoring system

The development of the construction process monitoring system has two functions: firstly to collect monitoring data (image processed data and sensor data) and secondly to generate and visualise operational data. Figure 1 shows the over view of the monitoring system for the construction process.

The monitoring and collection device has developed to capture video images of the construction process at the sub-assembly stage. The image processing system is developed to detect, track, recognise and identify objects from video images and sensor data captured by the device system. Detecting and identifying work, worker's behaviour, the construction module's working area and transfer are collected

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Papers are invited on the following topics:

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- Other aspects of **ship behaviour in shallow and confined water**, including ship – ship interaction, bank effects, ship behaviour in locks.

Benchmark data obtained by model test at Flanders Hydraulics Research are also available in order to validate numerical calculation methods and simulation models.

Authors are invited to submit an abstract of 250 words to info@shallowwater.be by 7 September 2015. For more information: www.mashcon2016.baw.de

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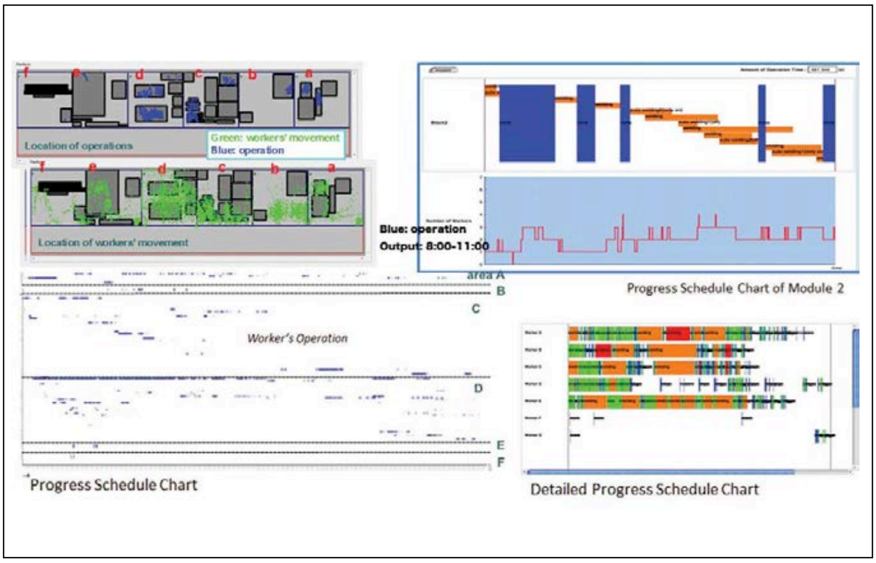


Figure 3; Operation Data generated by the Integration of Monitored Data: Construction Module's Operation, Worker's Operation, and Operations {Welding, Heating, Gouging, and Grinding}

by video image processing. In addition, collection acceleration sensor data is used to predict a worker's behaviour. Since the worker's position is necessary for monitoring, GPS data and Wi-Fi radio field strength are collected and processed. An RFID system is used to identify a worker.

In the function for generating and visualising operational data, collected monitoring data is integrated to generate operational data (4W1H: when, who, where, what, how) by the data processing system. This processing system analyses, classifies, tallies statistically and calculates the useful data from the image processing system, such as time and location, for effective management. The output of the monitoring system is given by the image and data processing systems. Many types of progress schedule chart (Gantt Chart) is generated from operational data and shown.

Data collection

The device is composed of a wireless video camera and video recording server. The video camera, which is placed in a construction shop, monitors the site and transfers video information via the wireless LAN to the recording server. Sorting through monitored data that is meaningful for effective management is handled by the image processing system that has a framework including the following main stages: object detection, object tracking, object recognition and identification.

In shipyard, welding and grinding operations are commonly performed in construction shops and they are considered key operations. Data for welding and grinding operations, such as their locations and durations, can influence or even determine the results of parts of the manufacturing and assembly and so on.

All of the crucial data cannot be recorded manually in shipyard workshops since these operations are performed many times every day, so for each operation there is uncertainty, which can cause extra costs. However, the proposed system is a possible way to solve these problems effectively at a low cost. Figure 2 shows the image processing for generating welding, grinding and heating operations.

In a construction workshop floor, many construction modules are waiting to be assembled by workers or moved away by cranes. Module location, amount of time for assembly and other related information influence or even determine the next batch of modules' working procedure as well as a quality of management.

Video image processing can also process moving objects such as workers and forklifts and analyse their movements. Workers and forklifts are typical moving objects in actual shops. The temporal difference–based motion detection method was selected as a main method for the detection stage to detect the movement of these two bodies. Contour-based tracking and the motion templates method are used as a main tracking method in the object tracking stage. In the recognition and identification stage, the following differences between worker and forklifts are used to recognise these two moving bodies in a video.

Two additional monitoring technologies, which are RFID (Radio Frequency IDentification) and accelerometers, are introduced to collect monitoring data in a monitoring system. That collected data is the identification information of workers for making the correspondence with image-processed data by worker's identification. RFID technology is utilised to make it to correspond to "operational" data of image-processed data.

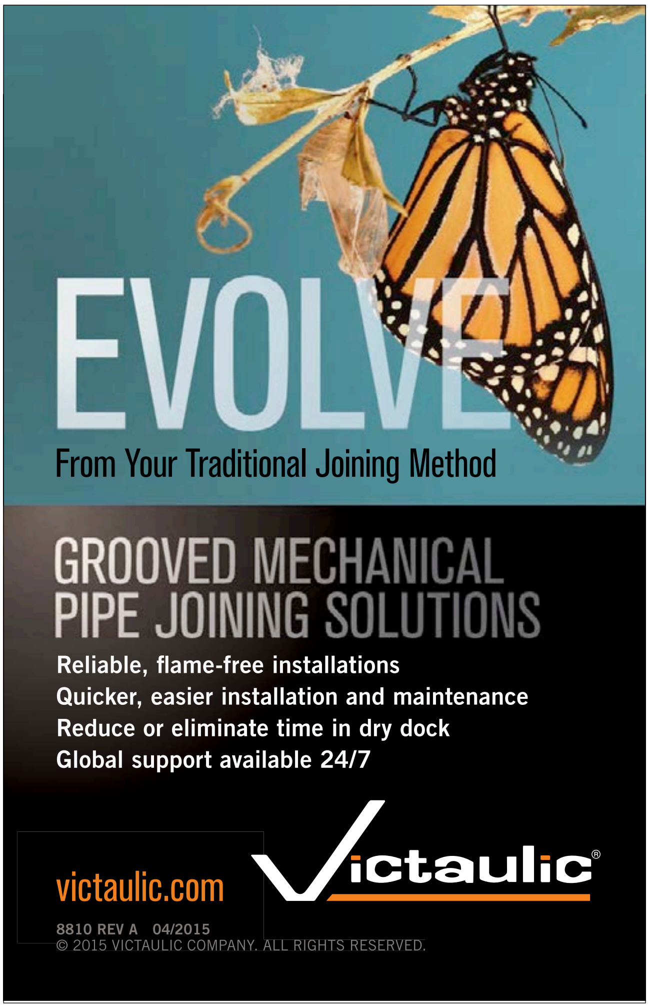
RFID tags are attached to operational tools, for example welding torches, and the RFID reader each worker has detects the RFID tags. The useful data of each operational tool of each worker can be acquired as the data detected by the RFID reader. It can be capture what and when each worker performed a task because operational tools and types of operation are in one-to-one correspondence. Accelerator sensors, which are built into smartphones, are utilised to estimate the worker's moving state (moving or stationary) by processing the acceleration data.

Generating operational data

The role of the function for generating operational data is to obtain all useful data for management, such as the time and location, from the image processing system and to analyse, classify, tally statistically and calculate the data for each body for feasible and effective management. In time management in construction, the sub-assembly lead-time is an important value that depends upon the assembly lead-time for the longest activity.

Basically, most operations occur around a construction module and workers do jobs with modules; in other words, the module is the centre and main object of sub-assembly in the construction shop floor of a shipyard. If we want to improve sub-assembly management, we need to pay more attention to the module, so the module should be chosen as the activity.

The lead-time for constructing modules is defined as having three parts: transportation time, operation time and wait time. Transportation time is a required time for transferring the module from one shop floor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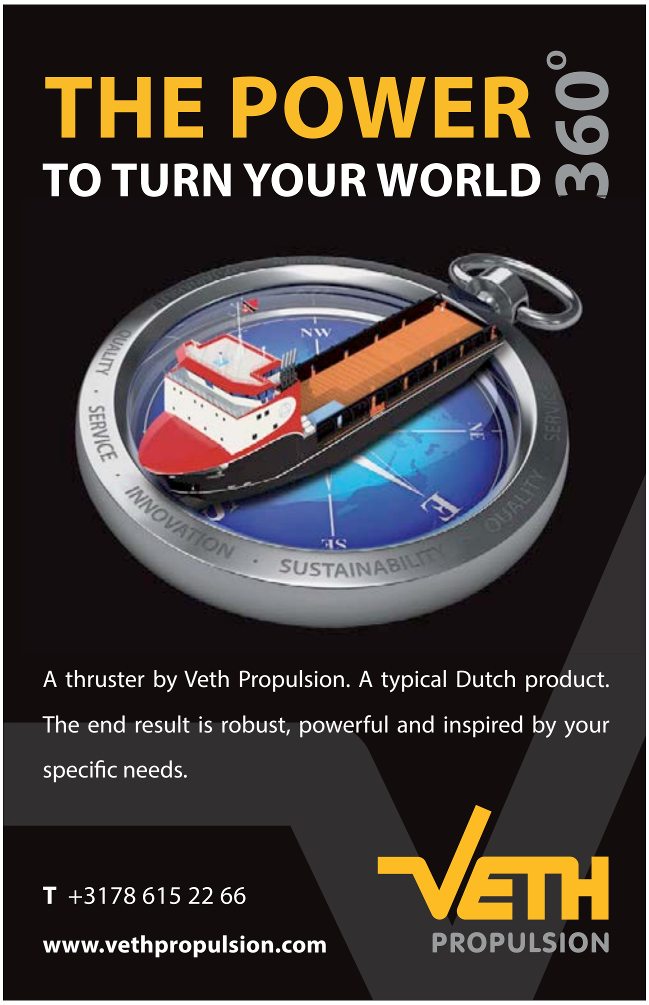
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to another shop floor. Operation time is the total time of the operation's performance. In this monitoring system, welding, grinding and heating operations are considered as monitoring targets. Waiting time is used to describe the time a module is waiting for an operation to be performed or to be moved.

After video image processing, the data processing system receives all data of interest such as the location of a module, location of an operation, location of a worker, duration of a welding operation, duration of a heating operation, duration of a grinding operation, duration of the stay time of a module and so on. All this data is analysed statistically to classify and calculate the move time, operation time and wait time for each activity automatically. The Gantt Chart of a modules' construction can be drawn based on the results of the data processing system. Figure 3 shows one example of data processing to generate operation data.

Work results information for staff, operations, and modules are necessary to comprehend the work situation. The methods for work record pre-processing, work record integration, and work instruction generation are introduced to facilitate the extraction of their collective work results information from the collected work records. However, it is difficult to use the collected raw work records directly; because data in the work records are isolated due to different devices and data processing system that collects the data.

In order to integrate the isolated data in the work records, a data labelling method is introduced. This method makes a label for the situations of workers, operations, and modules in space and time and integrating by those labels.

The position of each worker cannot be specified, but the worker to be made to correspond to RFID data can be specified. Therefore, in order to extract more detailed and correct operation information, RFID data and image-processed data are merged by making some data; operation time, position, kinds (welding, grinding, and so on), to correspond to each other between RFID data and image-processed data. As well as RFID data, the position of each worker cannot be specified only by acceleration data. Therefore, in order to extract position data of each worker, image-processed data and acceleration data are made to correspond to each other.

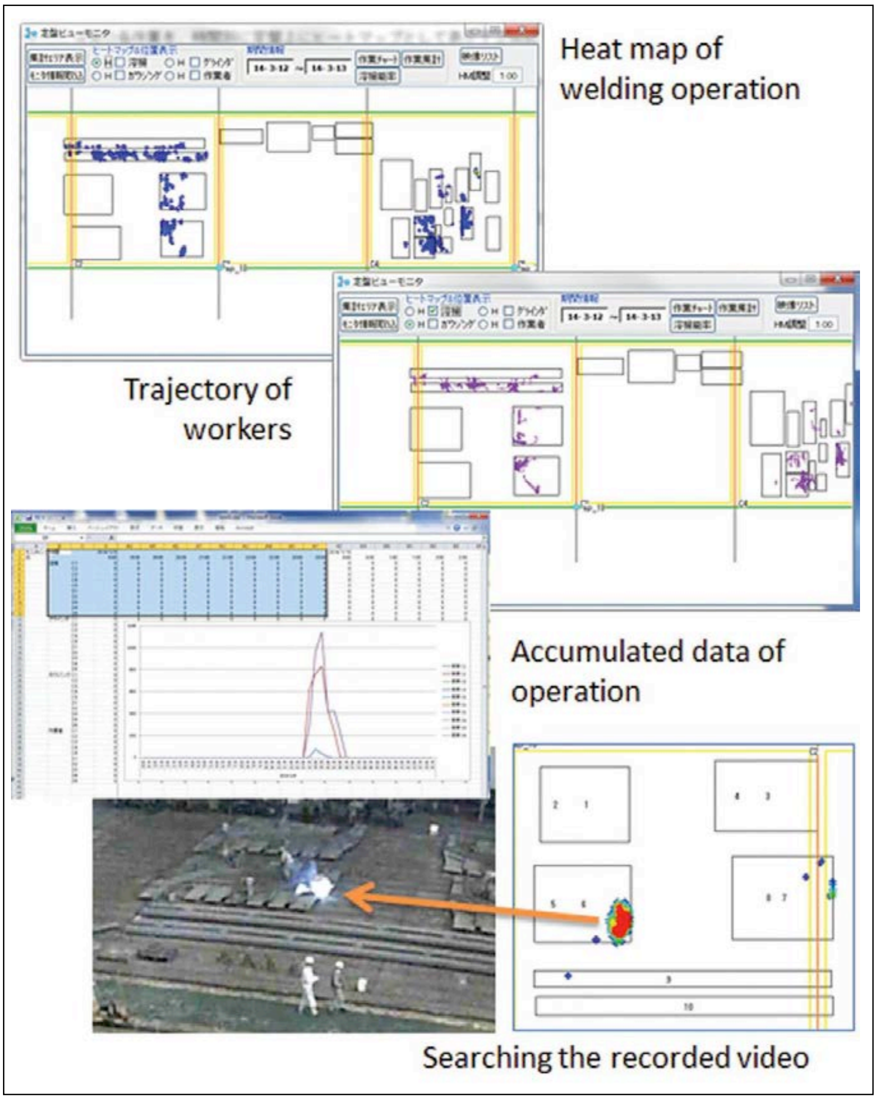

Figure 4: Snapshots of Monitoring Browser; they show heat maps of welding operations, trajectories of workers, and accumulated data of operations

As the function of visualising operation data, the browser of the Monitoring for Construction Process is developed. This browser, which is based on the Job Shop Planning system that can support Construction Scheduling and Layout Planning for Construction Modules, gives construction managers the following information. Figure 4 shows the some screen snapshots of this browser.

- Comparing the scheduled plan with monitored construction progress
- Checking productivity performance by accumulation of operation.
- Showing Gantt Chart of the construction schedule and heat map for working points and worker activities.
- Enabling the searching of the recorded video from the Gantt Chart enables to confirm the cause of the delay trouble in schedule.

Future plans

In order to improve the management of construction job shops in shipyards, we are developing a construction management monitoring sub-assembly system. We propose new methods for integrating monitored data and generating operation data in order to comprehend the current working situation of the construction shop floor.

Figure 5 shows the PDCA cycle for advanced construction management using the proposed Construction Process Monitoring System. We are developing a

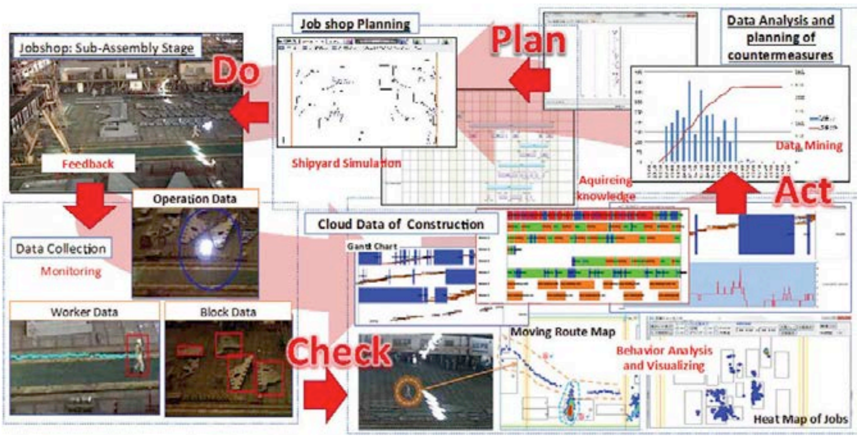

Figure 5: Overview of Advanced PDCA cycle using the Construction Process Monitoring System

monitoring system and integrating it with the other system to realise the following PDCA activities.

- Plan: Make construction schedule
- Do: Generation of Operation Data by Shooting Video, image processing and sensor data collection.
- Check: Browsing Current Progress of Construction and Find Problems
- Action: Changing construction schedule and simulate construction to find optimised construction plan.

For the image processing system, data processing system, algorithms with higher accuracy and lower processing times will be designed into the system. Machine-learning technology will be used in these two systems to help build shipyard construction site models, as well as models of objects of interest. *NA*

Abstract from a paper to be presented at the International Conference on Computer Applications in Shipbuilding (ICCAS) in Bremen, Germany on 29 September - 1 October 2015.

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Acknowledgements

This monitoring system is supported by the Nippon Foundation and the Japan Ship Technology Research Association (JSTRA). We would like to express our sincere gratitude to the Nippon Foundation for their financial support. JSTRA organised the committee to arrange shipyard experiments and meetings to discuss this study. We appreciate their help and committee members. *NA*

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Enter the gas age

In an appraisal of the immediate future for the maritime industry Wärtsilä believes the only way forward for owners is to choose gas power. Hence the move to design a new family of container feeder ships that will see merchant shipping, literally, enter the gas age

According to Wärtsilä's crystal ball the world's "addiction to fuel oil as a maritime fuel" is about to end. Perhaps not dramatically, but it is likely to fade over the coming years. Demand for fuel oil is "past its heyday" and it will become very expensive in the future, the only alternative in this scenario is LNG.

With that expectation in mind Wärtsilä Ship Design (WSD) has fashioned a family of three container feeder vessels, a 1,400TEU ship, a 2,300TEU vessel and the largest of the group a 4,000TEU ship. In addition there is the 2,400TEU container ro-ro design. However, the containership designs came after Wärtsilä had created dual fuel tanker designs.

As the company was already looking at tanker designs when it began to discuss future vessel needs the group had a look at how LNG would play out as dual fuel versions of its tankers. Even though there are still only 15 LNG bunkering facilities worldwide at the 8,000 ports around the globe, with another 32 proposed bunker sites to come the company believes that LNG will grow.

The bunkering infrastructure is an issue that needs to be addressed if LNG power is to be established and Wärtsilä believes that the infrastructure will be developed through regional shipping in the first instance, particularly in emission control areas.

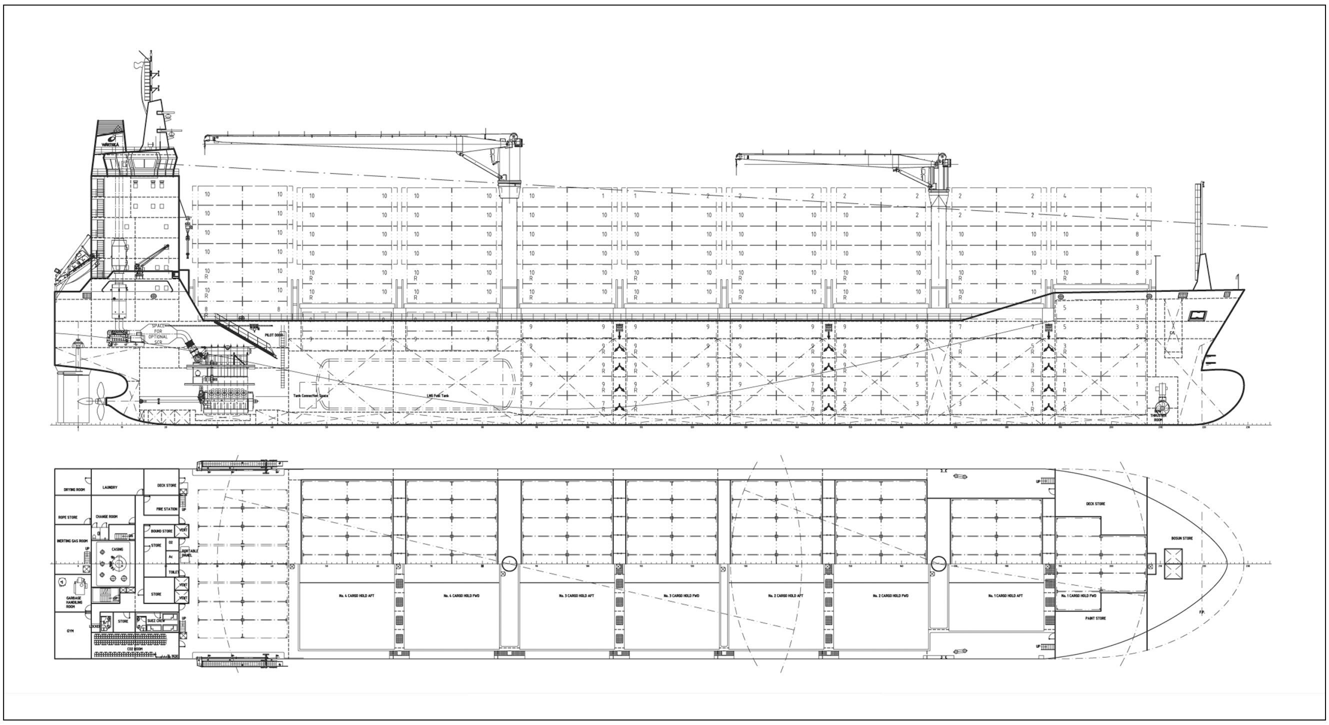
Jacob Høgh Thygesen, Head of Merchant Ship Design Solutions with WSD told *The Naval Architect* that China will be a major driver, with the country expected to own around 25% of the world's commercial fleet by 2030 and the Chinese already have bunkering stations at Zhoushan and Nanjing and Chinese interests have ordered 30 dual fuel ships to date with more expected in the future.

"The way they [the Chinese] are moving forward, combined with the government driven environmental legislation in Europe and America (Emission Control Area (ECA)/ SOx Emission Control Area (SECA)), are important drivers for the transition to LNG as a fuel," says Thygesen.

Thygesen went on to explain: "I think there is a two-way demand that pulls the shipping industry into the gas age. There is the commercial demand for better fuel efficiency, and an irrefutable demand for improved LNG infrastructure. Governments are already starting to look at incentives to improve this infrastructure, as they want to be on the LNG map. LNG bunkering is no longer a 'nice to have', it's an imperative."

Reasoning that coastal shipping will drive the spread of LNG Wärtsilä then identified container feeder ships as the first major movers into the dual fuel market because liner shipping has fixed schedules making it easier to predict demand. In addition, as container feeders

WSD80 1400, 1,400TEU dual fuel container feeder



General arrangement of the WSD80 1,400TEU feeder ship

TECHNICAL PARTICULARS

WSD80 1400

MAIN DIMENSIONS

Length over all, approx. ....162.90 m
Length PP. .... 153.85 m
Breadth moulded .... 26.00 m
Depth to main deck ....14.20 m
Draught, design .... 8.50 m
Draught, scantling.................................... 9.50 m
Deadweight (T= 9.50 m) .... 19,900 t

SERVICE SPEED & ENDURANCE

Max. Speed .... 18.7 knots
Service Speed..................................... 18.0 knots
Eco Speed .... 16.0 knots
Endurance, approx..............................8,800 nm
(service speed, design draught, with 15% SM)

TANK CAPACITY

HFO capacity, approx. ....1,60 m^3
MDO capacity, approx ....1,140 m^3
FW capacity, approx...............................350 m^3
Ballast capacity approx.......................9,100 m^3

STACK WEIGHT

Hatch cover 20'/40'/45'.......................70t/105 t
Main deck 20'/40'/45'..........................70t/105 t
In holds 20'/40'/45'............................ 150t/180 t

CONTAINER CAPACITY

Container position
On Deck...948 TEU
In Hold..472 TEU
Total..1,420 TEU

Reefer plug position
(on deck/in hold) ....176/158 FEU

Dangerous cargos in Cargo hold 1

Container intake at Design draught
HOMO 11t/TEU ....1,064 TEU
HOMO 14t/TEU ....914 TEU

Container intake at Scantling draught
HOMO 11t/TEU ....1,164 TEU
HOMO 14t/TEU ....1,024 TEU

Based on ISO standard container, a rel. VCG of 45%

E-PLANT 230 V/450 V

Power..450 V, 60 Hz
Lighting ....230 V, 60 Hz
Automation ....230 V, 60 Hz / 24 VDC

MACHINERY

Main engine (7RT-flex50 D), MCR .... 10,080 kW
NCR (85% MCR) .... 8,560 kW
Generator sets ......2 x 1,420 kWe + 2 x 1,065 kWe
Emerg. generator............................1 x 150 kWe
Bow thrusters................................1 x 1,081 kW
Propeller.........................1 x FPP, dia. 5,900 mm

LNG FUEL CONSUMPTION, DESIGN DRAUGHT

Service speed, no reefers ....31.5 t/day
Service speed, all reefers....................42.7 t/day
Eco speed, all reefers..........................32.4 t/day

PERFORMANCE, SERVICE SPEED, SCANTLING DRAFT

ME FGC 14t/TEU (g/TEU/nm).......................67.4
ME FGC 11t/TEU (g/TEU/nm).......................59.3

ACCOMMODATION

24 persons full HVAC in single cabins plus one Suez Crew cabin for 6 Suez

CLASSIFICATION

LR✠100A1, Container Ship, ShipRight (ACS(B)),

WSD80 2300, 2,300TEU container feeder

TECHNICAL PARTICULARS

WSD80 2300

MAIN DIMENSIONS

Length over all, approx. .... 187.70 m
Length PP .... 177.50 m
Breadth moulded .... 30.00 m
Depth to main deck .... 16.50 m
Draught, design .... 9.50 m
Draught, scantling .... 10.60 m
Deadweight (T= 10.60 m) .... 27,800 t

SERVICE SPEED & ENDURANCE

Max. Speed........ 19.0 knots
Service Speed........ 17.7 knots
LNG Endurance, approx........ 10,400 nm
(service speed, design draught, with 15% SM)

TANK CAPACITY

LNG capacity, approx........ 2,380 m³
MDO capacity, approx. .... 1,330 m³
FW capacity, approx........ 300 m³
Ballast capacity approx........ 11,600 m³

STACK WEIGHT

Hatch cover 20'/40'/45........ 70t/105 t
Main deck 20'/40'/45' .... 90t/120 t
In holds 20'/40'/45' .... 150t/180 t

CONTAINER CAPACITY

Container position
On Deck (6 tiers) .... 1,582 TEU
In Hold........ 688 TEU
Total .... 2,270 TEU

Reefer plug position
(on deck/in hold). .... 296/202 TEU
Dangerous cargos in all of cargo holds 2/3/4

Container intake at Design draught
HOMO 11t/TEU .... 1,506 TEU
HOMO 14t/TEU .... 1,295 TEU

Container intake at Scantling draught
HOMO 11t/TEU .... 1,746 TEU
HOMO 14t/TEU .... 1,522 TEU

Based on ISO standard container, a rel. VCG of 45%

E-PLANT 230 V/450 V

Power........ 450 V, 60 Hz
Lighting .... 230 V, 60 Hz
Automation .... 230 V, 60 Hz / 24 VDC

MACHINERY

Main engine (6X62DF), MC .... 13,500 kW
NCR (76% MCR) .... 10,260 kW
Generator sets.. .... 4 x 1,420 kWe
Emerg. generator .... 1 x 150 kWe
Bow thrusters........ 1 x 1,150 kW
Propeller........ 1 x FPP, dia. 6,500 mm

FUEL CONSUMPTION, DESIGN DRAUGHT

Service speed, no reefers .... 37.4 t/day
Service speed, all reefers .... 49.9 t/day

PERFORMANCE, SERVICE SPEED, SCANTLING DRAUGHT

ME GOC 14t/TEU (g/TEU/nm) 54.2
ME GOC 11t/TEU (g/TEU/nm) 47.3

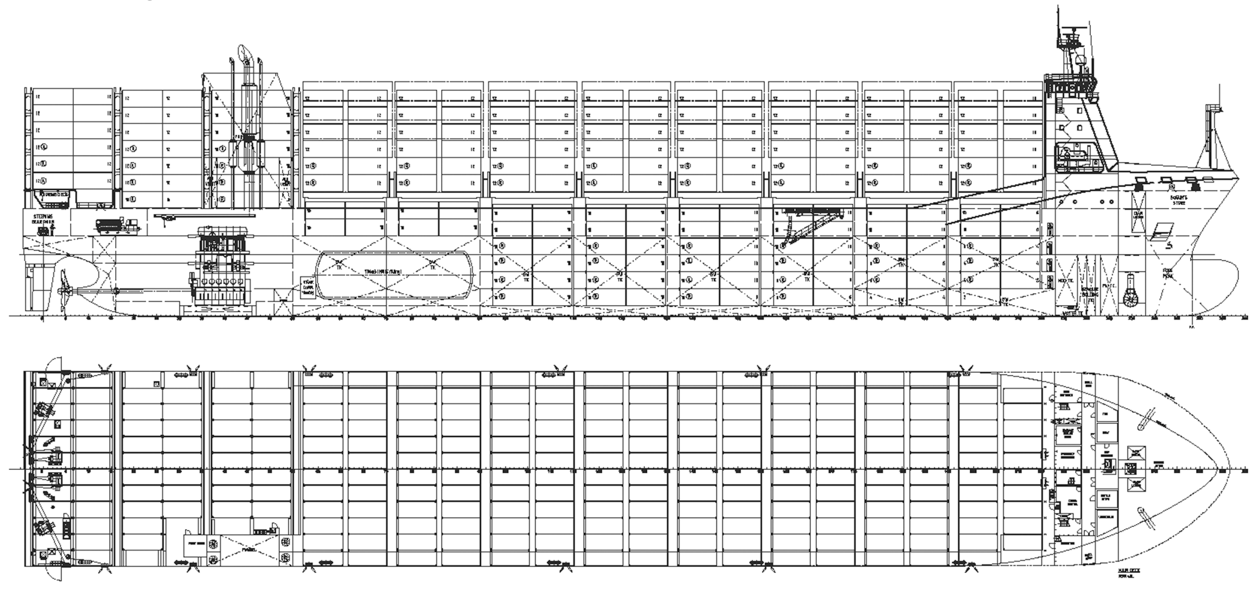
ACCOMMODATION

25 persons full HVAC in single cabins plus one Suez Crew cabin for 6 Suez

CLASSIFICATION

LR✠100A1, Container Ship, ShipRight (SDA, FDA, CM, ACS(B)), *IWS, LI, BoxMax(V,W), ECO(BWT, EEDI-3, IHM), ✠ LMC, UMS, NAV1, with descriptive notes: ShipRight(BWMP(T), SERS, SCM), CSA", GF

General arrangement of the WSD80 2,300TEU feeder ship



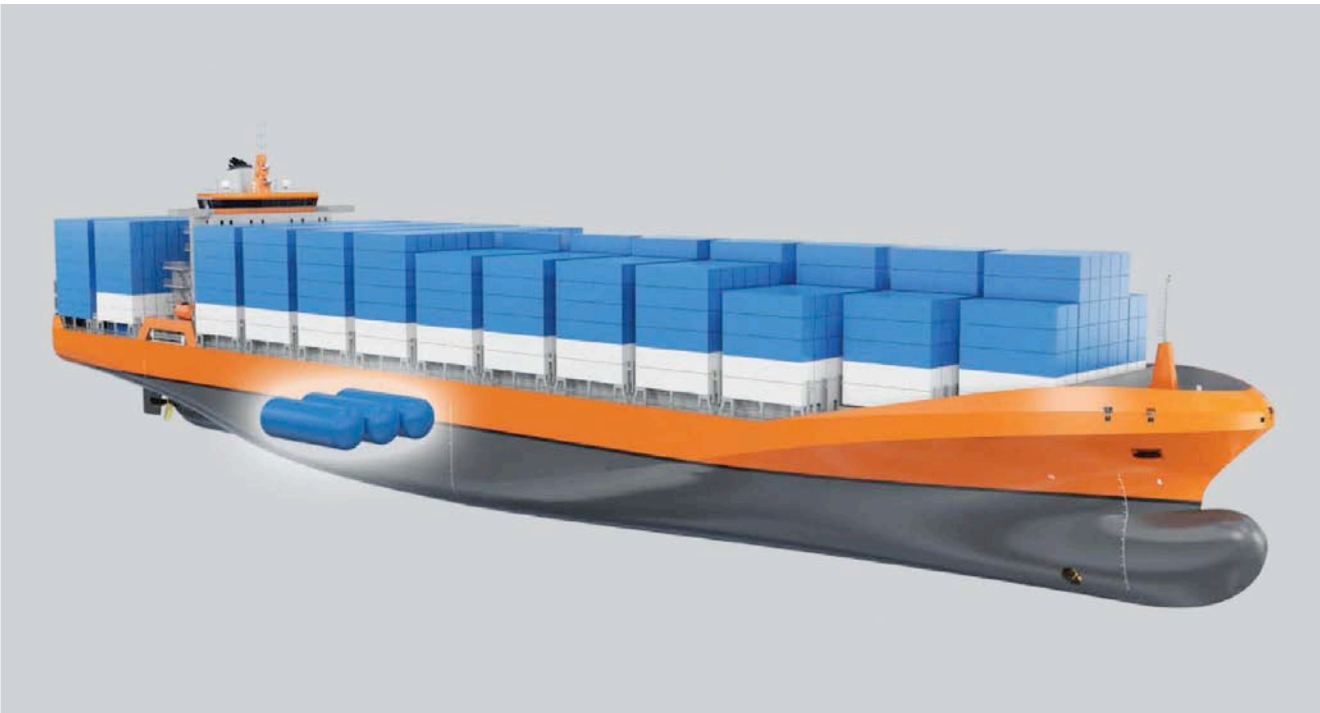
these vessels will need to operate within the ECAs and SECAs.

All of Wärtsilä's ship designs come in three versions, conventional with no modifications in order to meet new regulations; environmental with scrubbers and other additions to meet new rules; and clean, which is with a dual fuel capability. Gas-powered vessels will meet IMO Tier III regulations without further exhaust cleaning such as is necessary in the environmental version.

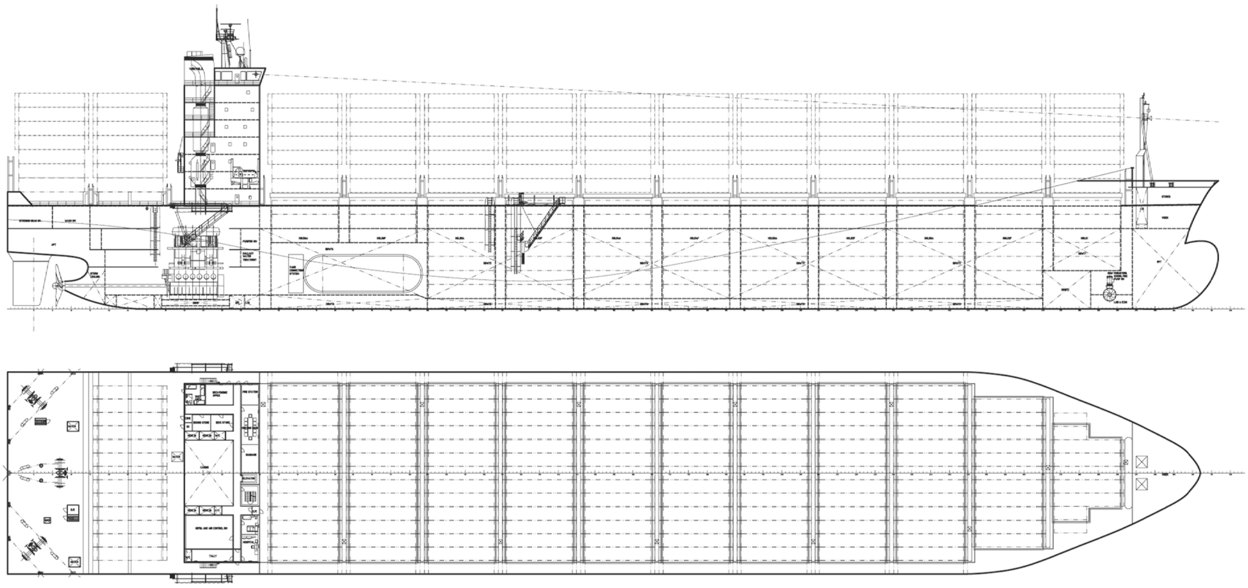
It is the costs, both operational and capital costs, along with the space necessary to install these extras that has convinced WSD that the conventional and environmental versions of its designs are not as attractive in the long term to the LNG configuration.

"The first two are suboptimal. We feel that it's evident that when they age and

WSD80 3800, 3,800TEU container feeder



General arrangement of the WSD80 3,800TEU feeder ship



TECHNICAL PARTICULARS

WSD80 3800

MAIN DIMENSIONS

Length over all, approx. ....224.80 m
Length PP ....213.80 m
Breadth moulded .... 37.50 m
Depth to main deck .... 19.10 m
Draught, design .... 11.00 m
Draught, scantling................................. 12.50 m
Deadweight (T= 12.50 m) .... 53,200 t

SERVICE SPEED & ENDURANCE

Max. Speed .... 19.2 knots
Service Speed .... 16.2 knots
Eco Speed. .... 15.1 knots
Endurance (MDO), approx ....21,000 nm
Endurance (LNG), approx..................7,750 nm
(service speed, design draught, with 15% SM)

TANK CAPACITY

LNG capacity, approx ....1,950 m³
MDO capacity, approx ....3,000 m³
FW capacity, approx............................... 500 m³
Ballast capacity approx.....................18,000 m³

STACK WEIGHT

Hatch cover 20'/40' ....70t/105 t
In holds 20'/40' .... 150t/180 t
Hatch cover 45'/48'/49' ....95 t
Lashing bridge arranged at all bays

CONTAINER CAPACITY

Container position
On Deck ....2,396 TEU
In Hold..1,444 TEU
Tota...3,840 TEU
Reefer plug position
(on deck/in hold) ....267/407 FEU
Dangerous cargos in all of cargo holds
Container intake at Design draught
HOMO 11t/TEU ....3,192 TEU
HOMO 14t/TEU ....2,715 TEU

Container intake at Scantling draught
HOMO 11t/TEU ....3,497 TEU
HOMO 14t/TEU ....3,039 TEU
Based on ISO standard container, a rel. VCG of 45%

ACCOMMODATION

26 persons full HVAC in single cabins, plus one Suez Crew cabin for 6 Suez

E-PLANT 230 V/450 V

Power..450 V, 60 Hz
Lighting ....230 V, 60 Hz
Automation ....230 V, 60 Hz / 24 VDC

MACHINERY

Main engine (6X72DF), MCR ....18,200 kW
NCR (50% MCR) ....9,100 kW
Generator sets...........3 x 1,600 + 1 x 2,770 kWe
Emerg. generator............................1 x 200 kWe
Bow thrusters................................1 x 1,200 kW
Propeller..........................1 x FPP, dia. 7,800 mm

LNG FUEL CONSUMPTION, DESIGN DRAUGHT

Service speed, no reefers ....36.4 t/day
Service speed, all reefers.....................50.6 t/day
Eco speed, all reefers...........................44.6 t/day

PERFORMANCE, SERVICE SPEED, SCANTLING DRAFT

ME FOC 14t/TEU (g/TEU/nm)........................26.7
ME FOC 11t/TEU (g/TEU/nm)........................23.2

CLASSIFICATION

LR✠100A1, Container Ship, ShipRight (SDA, FDA, CM, ACS(B)), *IWS, LI, BoxMax(V,W), ECO(BWT, EEDI-3, IHM), ✠LMC, UMS, NAV1, GF with descri tive notes: "ShipRight (BWMP(T), SERS, SCM), CSA"

Or equivalent

the market evolves – the replacements with LNG or clean designs will be essential – also from an economic point of view. The LNG vessels are coming. No way around it. I'm convinced that owners that 'miss this boat', so to speak, will be bypassed in the market. That's a given at this point," argues Thygesen.

He goes further to claim that in 10 years conventional second-hand vessels will have a low resale value, but dual fuel ships will hold their value, offsetting the higher capital outlay.

Wärtsilä includes some key performance parameters into all its designs and they are as follows:

- Risk mitigation: In introducing LNG power designers need to understand that ships must be as easy to build as possible. If a ship is too complicated and innovative, it does not make ends meet from a construction point of view. The designs need to have a feasible building strategy.
- Fuel efficiency
- Fuel flexibility
- Cargo capacity
- Redundancy in systems
- Lowest possible emissions

For all the container ships this has meant that there is flexibility in the design as well as ensuring that the vessels are efficient. That means the hull lines have been worked on through CFD to ensure the most efficient hydrodynamic design. In the case of the 1,400TEU container feeder this is a geared vessel with a high homogenous container cargo intake and the arrangement of the LNG tanks is designed to allow for conversion either to or from LNG power.

The 2,300TEU feeder is gearless and, unlike its smaller cousin, the accommodation block is situated forward of the cargo, meaning that crew have a more comfortable living area. *NA*

Crowley con-ro makes the rules

The fourth Wärtsilä Ship Design (WSD) container ship project differs to the other three in that it is a container ro-ro, and the first vessel of this design is already under construction at the Vision Technology Halter Marine shipyard (VTHM) in Pascagoula, Mississippi for Crowley Maritime. Below is an extract from a paper outlining the con-ro project

Operating under Jones Act regulations in the US, calling at ports in Florida and New Jersey and San Juan in Puerto Rico the WSD84 2,400TEU dual fuel con-ro will be the first LNG-powered container vessel to operate in the US when it enters service in May 2017.

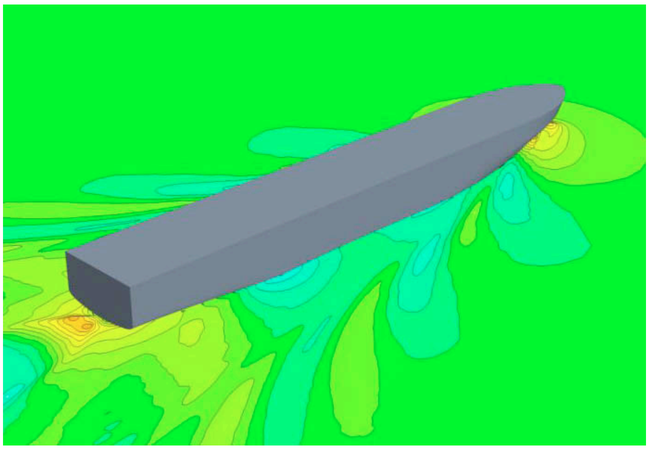


Figure 1: Pressure distribution and wave profile. Source: Wärtsilä

Crowley Maritime's new con-ro ships will replace four 730 and two 580 triple deck ro-ro barges, towed by Invader Class Tugs, sailing three times per week from Jacksonville, Florida, and once per week from Pennsauken, New Jersey. The fleet is part of a very extensive logistics train where any downtimes have dire consequences.

The fleet age, the new regulations and the increasing business potential were the main drivers for Crowley looking ahead of its competition, and beyond the currently employed shipping practices, to write down the requirements for a new fleet of vessels. These ships would also strengthen the bond with the company's values and culture of environmental stewardship in providing world class services.

Five representative operational profiles corresponding to the same number of trading routes have been analysed with corresponding duration and speeds and at various operating modes, with and without cargo. The most representative (i.e. demanding) operational profile was selected for the purpose of sizing the cargo capacity and layout, the propulsion configuration, the LNG tanks and Fuel Gas Supply System (FGSS), as well as the level of redundancy the vessel would need for uninterrupted service on any of the trade route, including Alaska.

In the upcoming years more stringent requirements for environmental compliance can be traced in the shipping industry. This makes it extremely important to identify the combination of those requirements which need to be applied to the vessel in order to match operational requirements and to ensure full regulatory compliance.

In addition to the existing in-force regulations the focus has shifted to the upcoming IMO regulations, mainly MARPOL ANNEX VI, which aims to reduce NOx, SOx, CO_2 and particulate matter from ship emissions. New limits with higher requirements for NOx emissions (Tier III) will be effective from 2016 and, higher limits for SOx emissions from 2015 in ECA areas, and a global sulphur cap from 2020 onwards.

At first, well-known statistical methods have been used to evaluate the preliminary required effective and delivered power and to size the propulsion plant accordingly.

An existing reference (1,800TEU) container vessel was used as the starting point in the initial hull form development process. Driven by the hydrodynamic aspects due to the arrangement of cars and containers, the hull lines have been amended by making the aft body fuller in the upper part of the hull. The main changes have been performed to enable adequate flow of vehicles in and out of the aft ro-ro superstructure through a single lane stern quarter ramp arranged on the portside.

LNG is a very space demanding fuel option, and minimising the capacity of LNG bunkers can be done by reducing the operational range, or by improving the efficiency of the design. Today's state-of-art tools for hull lines optimisation employ the use of computational fluid dynamics (CFD). For the CRV2400, CFD was used to evaluate the effective power, however, in combination with optimisation algorithms (through Friendship Systems) which allow certain modifications of the hull shape in predefined areas in order to find the optimum solution where the optimisation parameter would reach its maximum value.

Due to the complexity and the time-consuming process for the viscous-based CFD including rotating propeller (numerical propulsion test) it was decided to use resistance as a target for the optimisation. The thrust deduction factor remained an unknown parameter, but was carefully considered by using data available from the model tests.

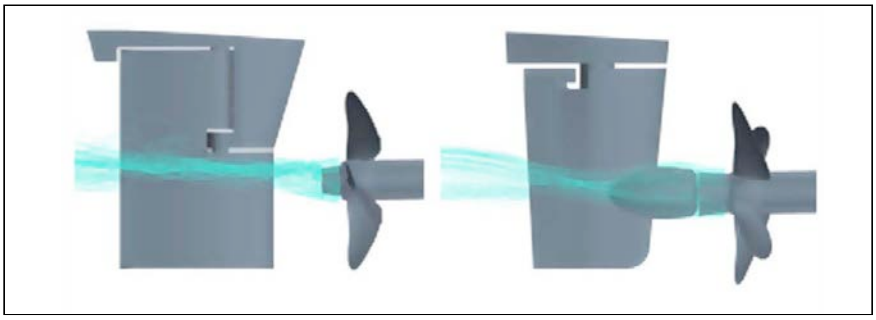


Figure 2: Conventional rudder vs. Energopac. Source: Wärtsilä

All major technical constraints and characteristics, including speed, deadweight, cargo arrangement, size and position of the LNG tanks were considered during optimisation.

Due to the specific requirements of the operational profile CFD optimisation of the hull form was based on the weighted combination of speeds and drafts.

This resulted in a less pronounced shape of the bulb, giving a somewhat less effective performance on the maximum draft, but better performance at intermediate drafts. Corresponding weighting was derived from the future operational profiles. Later, the vessel's performance was confirmed by model tests within 1% deviation in results from the CFD predictions.

Model tests

An extensive model testing programme was ordered at the MARIN testing facility in the Netherlands to assess the future vessel characteristics, and the following tests have been conducted:

- Resistance and self-propulsion tests for the complete set of the drafts
- Wake measurements tests
- Open water tests with stock and design propeller
- Manoeuvring tests
- Extensive sea-keeping tests

Very slender hulls in specific operational conditions are subject to parametric rolling. For this reason, the CRV2400 WB has had additional sea keeping tests performed to understand and map the field of occurrence and to ensure adequate mitigation measures.

Further, numerical simulations were performed with the optimised hull and a suitable Energy Saving Device (ESD) solution to identify any potential fuel saving benefit from installing such a device. Finally the EnergoPac solution was selected and successfully tested at MARIN.

Due to the combination of the twisted leading edge of the rudder and transition bulb it was possible to reduce the drag and eliminate strong vortex behind propeller.

Comparison results have shown that about 2% of power reduction can be expected when using EnergoPac solution.

Crowley is taking a bold step in bringing environmentally viable designs to market and these vessels are only a part of the whole programme. LNG bunkering facilities will be available in Jacksonville before the ship makes its maiden voyage ensuring uninterrupted supply of LNG as fuel and thus solving the perpetual 'chicken and egg' issue that many ship owners are faced with today. *NA*

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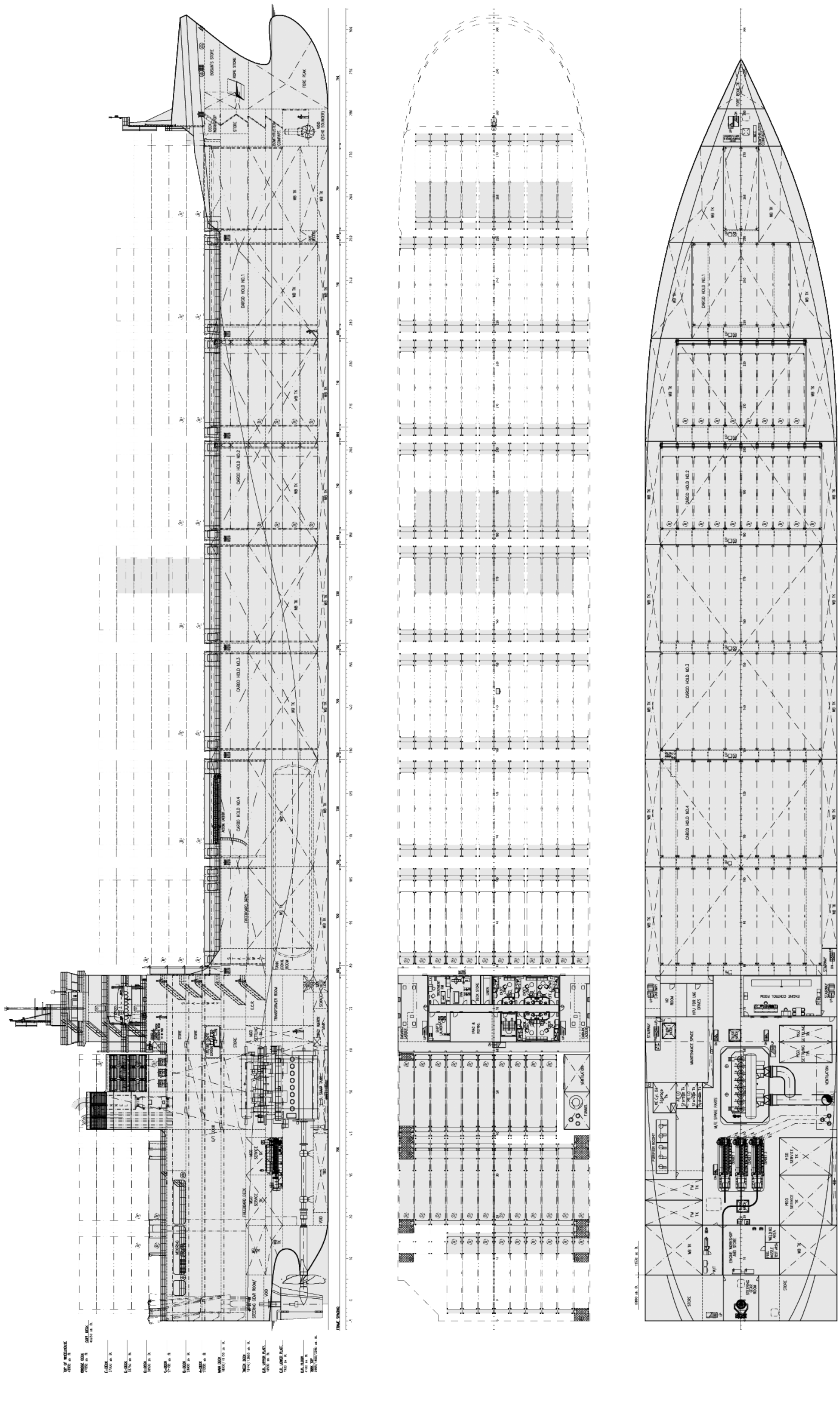
Dmitriy Sonechko is the General Manager, Project Development and Naval Architecture at Wärtsilä Ship Design Poland.

General arrangement of the WSD84 2400 LNG



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Keeping nature at bay

As soon as a vessel is launched slime, weed, barnacles and other marine organisms enthusiastically try to attach themselves to it. Immense effort has been spent over the millennia in either removing these unwanted creatures or in attempting to make the bottoms of ships so unattractive to them that they go elsewhere. Richard White reports

Broadly speaking there have been three main lines of attack; by sacrificial sheathing to provide a layer to keep worms from boring into the main planking of the vessel; metal sheathing to provide mechanical protection against borers and a chemical defence against attachment, and coatings or compositions to protect the structure and repel or poison marine life. More recent developments in super-slippery coatings, such as those that have no firm grip for organisms and are easily washed away.

Favoured methods have changed over the centuries along with developments in ship materials and construction and today coatings continue under intensive development to make them even more effective, smoother, longer lasting and less hostile to the environment. Many INA and RINA papers have dealt with the question of anti-fouling and it is instructive to delve into some of the early ones when the problems of wooden ships were to some extent solved and the transition to iron ships was causing immense problems of marine fouling.

In 1863 WJ Hay, the Admiralty Chemist, presented a paper on copper and other sheathing for the Navy. Before presenting his own ideas and findings he gave a brief historical review. Wood sheathing was used in the 15th century to keep the soft caulking of oakum and tallow from coming out and to prevent a destructive action of the different species of sea worms. In the 17th century in the UK lead sheathing fastened with copper nails became quite popular and continued until about 1770. But lead sheathing was of much greater antiquity and Hay quoted a 15th century work on naval architecture which stated that lead sheathing was used in the 2nd century and a vessel which had lain sunken and neglected for above 1300 years was recovered from a lake. "The pine and cypress of it had lasted most remarkably. On the outside it was built with double planks daubed over with greek pitch and caulked with linen rags and overall there was lead sheathing fastened on with little copper nails".

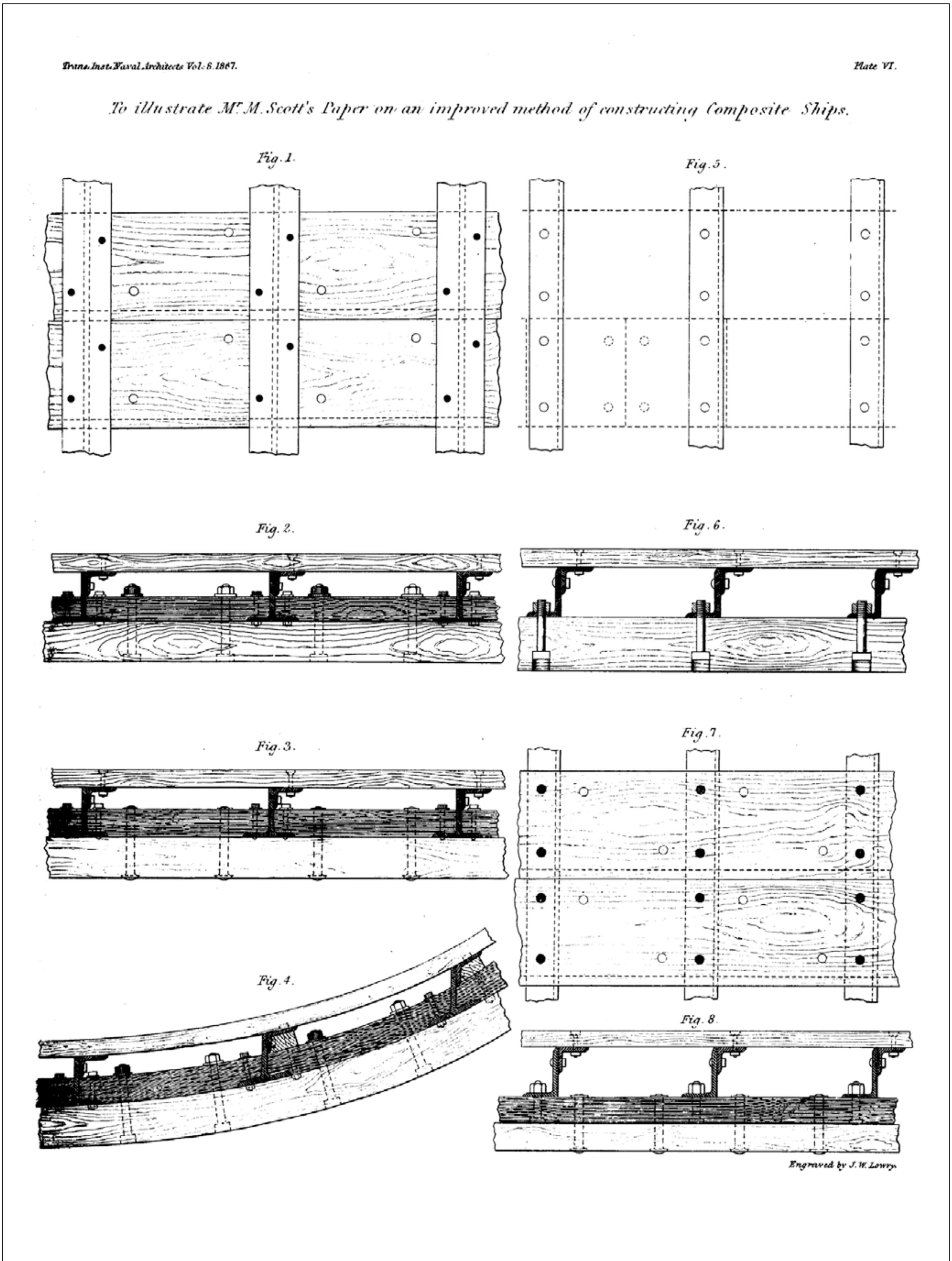
In the early 18th century the possibilities of copper sheathing were recognised. The Royal Navy had a major problem with fouling of warships and was keen to try different solutions. In 1761 HMS Alarmed was sheathed with thin copper, sent to the West Indies station and in due course examined. 'The sheathing was then found to have answered well in keeping the bottom comparatively free from the occasion of barnacles etc'. More vessels followed experimentally and by 1780 the whole Navy was coppered.

At which point major problems appeared. It was discovered that through the connection of the copper sheathing with the iron bolts in the bottom and the pintles in the rudder, oxidation had taken place to a great extent and that from careful examination it was discovered that within a period of three or four years the iron fastenings were injured so much as to render the ships unfit to be sent on foreign service. A mixture of pitch and tar was put over the ends of the bolts and other iron work in the bottom to prevent the contact of the two metals but this entirely failed in protecting the iron. The injury to the fastenings assuming such a formidable aspect that 'the Navy Board contemplated in 1783 discontinuing copper sheathing, but a suggestion of the use of bolts of mixed metal instead of iron for fastenings for the lower parts of the ships was approved of and adopted for a time, however, before the end of that year copper instead of iron bolts were ordered to be used in all ships'.

The bulk of Hay's paper was taken up with the unpredictability of copper sheathing. Sometimes the copper lasted extremely well yet on other vessels it wore away rapidly or perforated quickly.

One cause was seen as the widely varying composition of copper sheet. 'There are fifteen or sixteen different species of copper ores in the different parts of the earth unlike one another in their chemical constitution. In most of them the metal is united with sulphur, iron, zinc, antimony, lead, arsenic, silver and gold: these ores in some cases pass through ten or twelve different processes, the final one being deoxidising by wood, coal, coke or charcoal.' Another cause was electrolysis and in 1823 the British Admiralty enlisted the help of the Royal Society in the form of Sir Humphrey Davy to investigate the best method of manufacturing copper sheathing and preserving it from corrosive effects. This led to a better understanding of electrochemical effects and Davy demonstrated that copper could be protected by a small amount of a sacrificial metal such as iron or zinc which corroded preferentially. Perhaps not surprisingly the corollary was that copper sheathing would oxidise away less rapidly in sea water but it would lose its anti-fouling effect. In the discussion to the paper, taking place at a time when ships armoured with wrought iron were coming into use, it was noted that if a wooden ship was armoured and the armour carried a few feet below the waterline, much of the copper sheathing over the wooden hull would vanish. Investigations were also made into the durability of sheet copper from different oars and different sources produced by different methods without conclusive results. It appeared that so much depended on the micro composition and the way the resulting copper was rolled.

Two layers of planking was considered to provide a strong composite structure with less risk of electrolysis among the plank fastenings, the copper outer sheathing and the iron frames



For example old copper sheathing was typically removed and re-smelted for further use but often the sheathing made from this material was less durable than the original. Various copper alloys were developed, in particular Muntz metal used for sheathing with good results but copper sheathing of both merchant and naval vessels continued to be a good investment. The words 'copper bottomed' entered everyday language as an indicator of a high quality product or investment.

The same year, Hay returned to the fray with a paper on protecting iron ships from oxidation and fouling. He drew attention to an experiment tried on a vessel called *Rocket* in 1845 using a copper oxide coating on the iron plating. This seemed satisfactory, so for comparison the same vessel was treated like a zebra with alternative stripes of red lead and copper oxide composition. When docked a year later 'she presented a curious appearance: many of the red lead patches were corroded and had weeds three or four feet long growing into them, while the patches of copper composition were generally covered with a little slime but no weeds or corrosion'. The copper based composition was made up from the scale separated from sheets of copper during the pickling process after they had been rolled.'These scales are principally sub oxide of copper with a small proportion in the state of peroxide, they are very very pulverulent and require little labour to bring them into a very fine powder and they are prepared for application by being mixed with a varnish made of vegetable pitch and rectified naphtha. An improved process and one easier to keep the components from separating out was to boil the copper compound in linseed oil, adjusting it for application with turpentine. He considered that the anti-fouling action was what we would now call a self-polishing one where the constant action of the sea water upon the surface of the copper and the coating continually removes a proportion of the varnish and exposed the facets of oxide of copper 'which being in a most favourable state for combination with the chloric acid an oxi-chloride is formed and is immediately removed by a solution on the water leaving no oxide to act galvanically on the iron and from the rapid removal of the oxi-chloride off copper the adhesion of animal or vegetable substances is prevented.' In the discussion which followed the paper Mr Peacock talked of his early experiments with copper and then his development of a coating based on 'the scrapings from the backs of fishes.'

HMS Gannet, preserved at Chatham Historic Dockyard in the UK, is a good example of composite construction using copper sheathing, two skins of teak, and iron framing. At service displacement, less of the copper would show above the waterline

Despite the claims, most of these early coatings for iron ships were short lived or ineffective and the search continued. In the 19th century environmental considerations did not have the importance they have since achieved and little by little effective anti-fouling for iron ships was developed with coatings incorporating biocides including poisons such as arsenic.

Between the eras of the wooden ship and the iron ship there was a brief vogue for combining the two in the so-called composite ship. This construction was popular for fast merchant ships, particularly the tea and wool clippers, and some warships. By combining iron framing for increased interior volume and extra strength with wooden planking, the result was a vessel which had many of the benefits of iron construction yet could be copper sheathed for anti-fouling and protection against wood borers. There were many theories as to how best to construct these vessels to avoid corrosion between the various materials, for example a multi-skin system put forward by Michael Scott in his 1867 paper 'On an improved method of constructing composite ships'. A popular sheathing metal was Muntz metal, also known as yellow metal, a brass comprising about 60% copper, 40% zinc and a small amount of iron. This was economical and effective and can be seen on the recently restored clipper *Cutty Sark* in London. At Chatham the restored Royal Navy steam sloop *Gannet* of 1878 is a fine example of composite construction, with two layers of teak planking on iron frames with copper sheathing

But it was clear that the future lay with iron, and in due course with steel, creating a powerful incentive to develop coatings for both corrosion resistance and anti-fouling properties. One hundred and fifty years after the period we have been dealing with the search is still on for ever smoother, more durable and environmentally neutral solutions. *NA*

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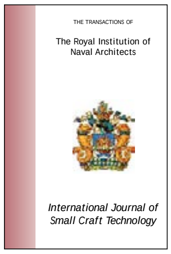

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