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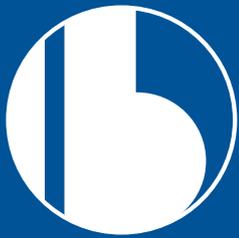
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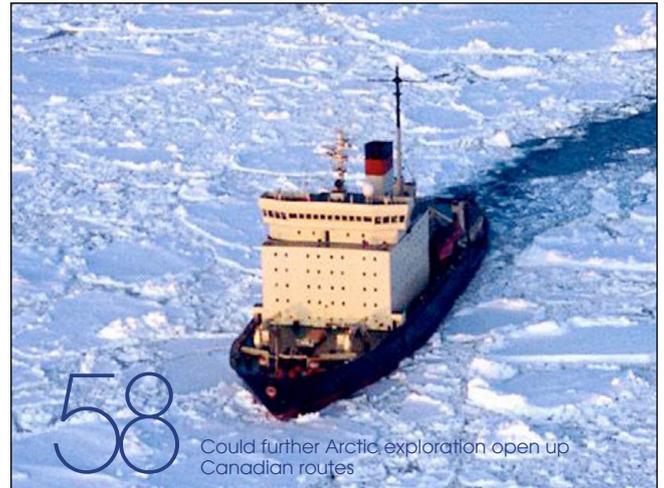
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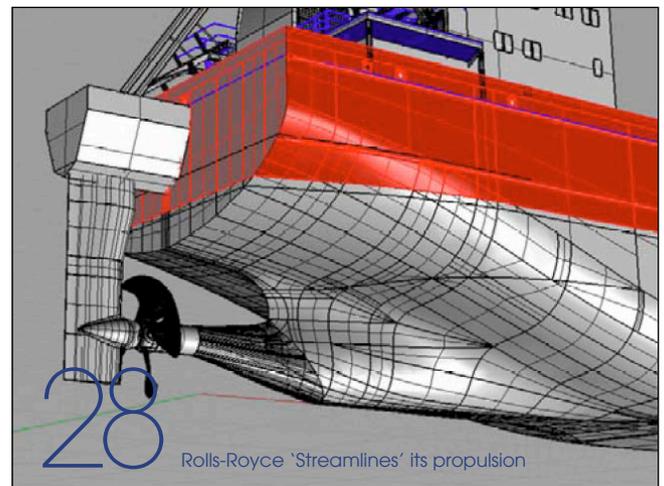
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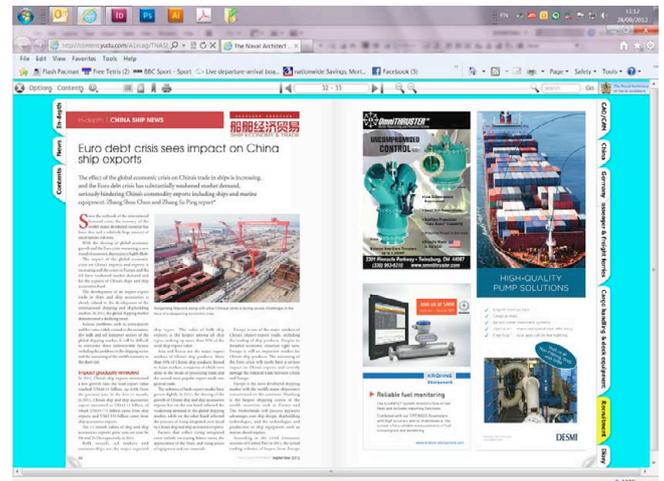
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## Digital Editions

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All submissions of abstracts are to be submitted online at:  
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Further instructions regarding abstract format and guidelines are available on the website.

### Authors are invited to submit abstracts on the following topics:

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- Commercial Ship Operations
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- Maritime Environment Protection
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## New Year new carbon footprint

Burning issues; The IMO's EEDI regulation comes into effect from 1 January

As we usher in another year, the echoes of the last strains of Auld Lang Syne still ringing in our ears as yet more IMO regulation comes into force. However, this year the new regulation is different. This year sees the introduction of the first legally binding treaty on climate change since the Kyoto Agreement in the late twentieth century.

From the beginning of this month the Energy Efficiency Design Index (EEDI) came into force for many ships. And the IMO believes that the new regulatory regime will change the nature of shipping and of ship design.

"As from 1 January 2013, following an initial two year phase zero when new ship design will need to meet the reference level for their ship type, the level is to be tightened incrementally every five years, and so the EEDI is expected to stimulate continued innovation and technical development of all the components influencing the fuel efficiency of a ship from its design phase," says the IMO.

Over the coming years new vessels will have to meet progressively more stringent regulations, they will need to be cleaner and more efficient.

"The EEDI for new ships is the most important technical measure and it aims at promoting the use of more energy efficient (less polluting) equipment and engines. The EEDI requires a minimum energy efficiency level per capacity mile (e.g. tonne mile) for different ship type and size segments," explains the IMO.

That EEDI is the final word in developing a cleaner maritime industry is unlikely, but what it definitely has been is a spur to innovation. Slow steaming is certainly a product of economic imperative; as the price of oil soared the returns for the ship owners and operators collapsed, slowing ships down saved significant costs for owners.

Not so long ago, perhaps two years ago, some shipowners believed that slow steaming was a temporary phenomenon that would disappear when the global economy showed signs of recovery. Since then the mood music in the industry has changed its tempo and when owners are ordering vessels they accept that the ships will be sailing at far slower speeds than in the pre-2008 era.

This factor alone has helped the industry make significant strides towards becoming a cleaner industry, but designers are already working on making ships far more efficient than could have been envisaged even two years ago.

In this month's Green Shipping feature a number of designers talk about the work that is currently under way that will become available in the coming years. The STREAMLINE project that looks at large Area propellers and the Walvisstaart POD innovation for new vessels is being recognised and new efficiencies are being realised.

Academics at the University College London are studying methods for evaluating the effectiveness of add-ons to ships that help reduce fuel consumption and make older ships cleaner. In a similar project FORCE Technology in Denmark is using CFD and tank tests to evaluate the effectiveness of modifications to existing ships.

It is a fair bet that few of these projects would have seen the light of day without the initiative from the regulator in setting out the EEDI standard. New regulation could as a consequence literally revolutionise the design and operation of ships and the shipping world. By changing the focus from economic imperatives to social necessities owners are being forced to accept that they too have a responsibility to minimise the pollution from their operations.

If EEDI is the start of a change in the mind-set of a hitherto environmentally devil may care industry then ring out the old and ring in the new. *NA*

### Have your say

The Naval Architect would like to invite its readers to take part in our online survey, where you can have your say on which magazine sections and feature topics are of the most interest to you and what you'd like to see more of in future. All participants will be entered into a prize draw, with an iPad up for grabs for the lucky winner. To participate in the survey please visit: <https://www.surveymonkey.com/s/DH6SJVN>.

## Newbuilds

## Fuel sharing first

Greek owner Alpha Tankers and Freighters International is the first company to order LNG carriers with fuel sharing engines from MAN Diesel & Turbo.

The two 160,000m<sup>3</sup> LNG carriers will be built at STX Offshore & Shipping in Korea and will see two MAN 51/60DF and two 8L51/60DF engines installed on each ship, making the vessels IMO Tier II compliant in diesel mode and Tier III compliant when burning LNG.

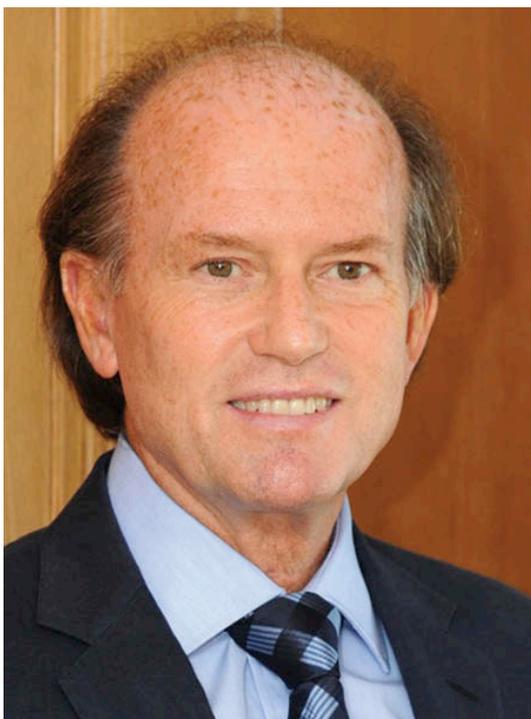
However, the engines are capable of burning both LNG and HFO or distillate fuel simultaneously, offering owners the option to 'fuel share' when boil-off gas is in short supply.

MAN's fuel sharing system was first offered to owners in 2009, but this is the first firm orders that the Danish engine builder has received. The engines are due to be supplied from the company's Augsburg plant in Germany and will be delivered to Korea in the fourth quarter of 2013. The two original vessels, the owner has options for more ships, are due for delivery in 2014 and 2015.

## Wreck removal

## Raising the stakes

Costs for the recovery of the wreck, *Costa Concordia* have doubled because of the Italian Government's insistence that the vessel is removed in one piece, says International Salvage Union (ISU) president Andreas Tsavlis.



Speaking at the ISU's annual lunch in London last month Tsavlis said that if the ship was cut and removed in sections the costs could be reduced to around US\$200 million, but "the fear of pollution" meant that the Rome had insisted the vessel is removed in one piece and that, says Tsavlis, has driven costs up to around US\$400 million.

## CSR-H

## Negative industry feedback on CSR

Initial responses from industry to the harmonised Common Structural Rules (CSR-H) was less than complementary following a series of seminars organised by the International Association of Classification Societies (IACS) in a number of key locations.

Feedback from owners, yards and designers suggested that CSR-H, which harmonises the design of tankers and bulk carriers, would slow the design process and ultimately drive up costs.

IACS chairman, Tom Boardley, confirmed that following a "very productive" meeting of the IACS Council in December the industry review period has been extended.

Aidan O'Donnell managing director at the ABS and Lloyd's Register (LR) joint venture CSR Software (CSRS), which aims to produce software for the newly harmonised rules, told *The Naval Architect* that there was a conflict between the approaches of class and industry engineers: "Engineers always complain regardless, it's because we're driving safety and they're trying to keep costs down," says O'Donnell.

Essentially, the scope the CSR-H is far broader than the previous version and this offers engineers more analysis. "We have to produce software that does more work to assist the engineers, added O'Donnell.

An ABS statement said: "From our perspective the harmonised Common Structural Rules are coming and it is the role of ABS, through our joint venture with Lloyd's Register, to help reduce the uncertainty that comes with any new standards by developing an effective software tool that minimises the impact of CSR-H."

ABS and LR established CSRS in the spring of 2011 in order to develop the software necessary to use the CSR-H, which are expected to be available in 2014.

However, "Shipyards have made it clear that they want to be provided with software that is comprehensive, fast, simple-to-use and defect-free from the outset and CSRS is working closely with industry representatives towards that goal," read a joint ABS and LR statement.

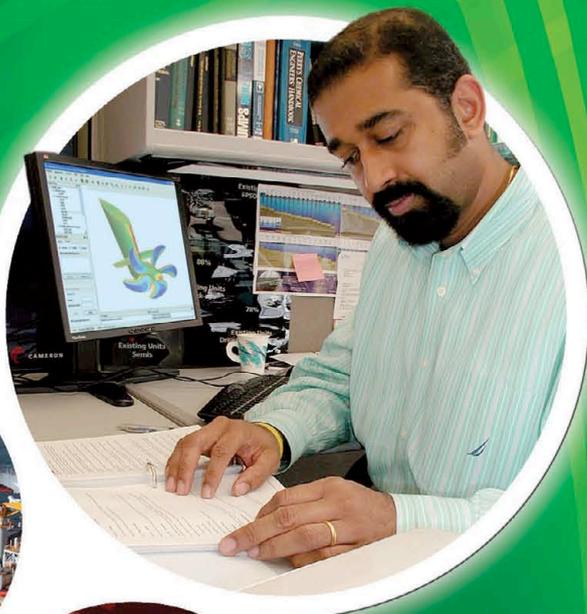
ISU president Andreas Tsavlis says government involvement increases cost of salvage

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“One of the lessons learned from the release of the existing CSR for tankers and bulk carriers is the importance of having mature software aligned with the final Rule version before it goes into effect,” added the class societies.

O'Donnell added that CSRS was developing the CSR-H software as the rules were being amended with a view to the software being available shortly after the rules are approved. The first draft of the rules was released on 1 July 2012 and the next draft is due in late March or early April of this year, says O'Donnell.

#### Cruise

## Italian yard delivers luxury liner

Concentrating on the super luxury market Compagnie du Ponant, part of the Bridgepoint Group, has ordered *Le Soleal*, from Fincantieri.

The ship was launched in early December at the Ancona shipyard and is expected to be delivered in June 2013. The yard said the vessel is “essentially more like a mega yacht in size and for the paramount attention to the interior fit-out”.

*Le Soleal* is the third ship in the series delivered to the France based cruise operator following the deliveries of the sister vessels *LAustral* and *Le Boreal*, the two mini cruise ships were delivered in May 2010 and April 2011 respectively.

As with its sisterships *Le Soleal* is equipped with the very latest in environmentally friendly technology, while its small size means that it will be able to reach ports and destinations inaccessible to larger vessels.

The Compagnie du Ponant, based in Marseille, currently has a fleet of three cruise ships targeting the super luxury market. Founded in 1988, it became a member of the Bridgepoint Group in 2012.

Since 1990 Fincantieri, has delivered 63 cruise ships. Another seven ships are being built or will be built between now and 2016 in the Group's shipyards.



In addition to the ships under construction, Fincantieri has recently reached two important agreements: with the US group Carnival Corporation for the construction of two cruise ships for the Holland America Line and Carnival Cruise Lines, and with Viking Ocean Cruises for another two cruise ships.

#### Newbuilds

## Jinling secures B.Delta37 order

Chinese shipbuilder, CSC Jinling Shipyard, has signed an agreement with Oldendorff Carriers GmbH & Co of Germany for a series of three ships plus options of B.Delta37 open hatch general cargo ships.

The B.Delta37 vessels are around 38,300dwt with a length of 180m and a beam of 30m with a cargo capacity of 48,500m<sup>3</sup> of hold space.

Designed by the Finnish outfit Deltamarin, the B.Delta37 design is claimed to be fuel efficient, consuming 17.9tonnes/day at 14knots at 9.5m draught with a 15% sea margin. Deltamarin says that the B.Delta37 is around 30% more efficient than the EEDI requirement that will come into force this month.

This latest order brings the number of firm B.Delta37 orders to 21 units and the total number of newbuilding orders of different types of B.Delta designs to 38 for a variety of owners.

“Deltamarin's design contract will include the Basic Design, Detailed Design, Technical Procurement handling as well as a Site Team to ensure continuity all along the design phases to production,” said a Deltamarin statement.

The first ship in the B.Delta series was delivered to the Canadian Steamship Lines and that ship has performed as expected, following sea trials and the model tests, says Deltamarin.

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## Correction

In our October issue we stated that Kang Yang-soo was the former senior vice president of Sungdong Shipyard. Sungdong would like to clarify that Yang-soo was SVP of sales and marketing and that at no point was he running the company. Furthermore, we wrote that Sung Yang Ha was appointed to run the company, but it was in fact Sung Yong Ha who took on the role at the yard. *The Naval Architect* would like to apologise to Sungdong for these misunderstandings.

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On the launch pad, *Le Soleal* will be delivered to Compagnie du Ponant this year



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## Concerns remain over passenger ship damage stability

If the technical report into the sinking of *Costa Concordia* is not yet available, there have been plenty of questions raised in recent months about the safety of passenger vessels and whether rules need to be tightened further, writes Sandra Speares.

While few people have been prepared to comment on the likely results of investigations into the capsizing of *Costa Concordia* ahead of a technical report by the Italian authorities, which will be preceded by a criminal investigation into the accident that cost 32 people their lives, Allan Graveson, senior national secretary of seafarers union Nautilus International has been vocal in expressing his concern about recent submissions to the IMO's Maritime Safety Committee, in particular those made by the United Kingdom, and the most recent report by the Italian authorities on the *Costa Concordia* accident.

Graveson described the UK submissions as "quite dramatic" and expressed his concern about the stability, watertight integrity and buoyancy issues raised.

Graveson said the possibility of an oblique collision was a major worry with the way ships were being built with high stack height and narrow beam. "Stability is on a knife edge when the hull is intact".

*Costa Concordia* was built before the new probabilistic requirements for cruise newbuildings came into force, and was fully compliant with regulatory standards, but a series of papers by the UK delegation to IMO, albeit aimed at the ro-pax sector, did raise questions about damage stability, watertight integrity and the safe return to port principle for passenger ships.

In the case of *Costa Concordia* as the preliminary Italian report pointed out, the flooding of five watertight compartments, including those containing vital equipment, meant that the extent of damage was beyond the ability of the ship to survive.

However, the Italian report also pointed to other measures, over and above those contained in SOLAS amendments including more partitioning and sub-partitioning of each watertight compartment to limit the effects of free surfaces; discontinuity between compartments containing ship's essential systems, in order to preserve their functional integrity; and the availability of essential systems in case of emergencies, in particular redundant steering of the ship and systems to counteract flooding and heeling; as well as the suitable energy production and distribution system, for example a second emergency diesel generator located in another main vertical zone in respect to the first emergency generator and above the most continuous deck.

According to one of three submissions to MSC by the UK, "SOLAS requires that the safe return to port concept provides for essential equipment to remain operational following the loss of defined extents of the ship as a result of fire or flooding; an aspiration to the ship being resilient, self-sustaining and its own best lifeboat.

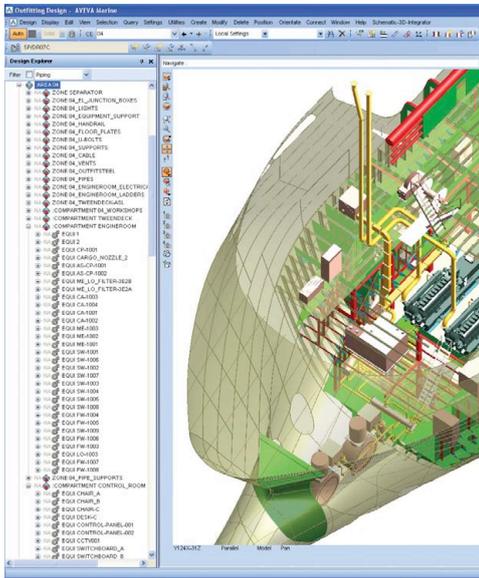
"Essential systems must remain operational following the flooding of any single watertight compartment; however, there has been no additional provision made for sufficient stability for the ship to be considered viable for navigation in this condition. The United Kingdom considers this to be an important omission since there would appear little advantage in having all essential equipment remaining fully operational whilst abandoning the ship as a result of insufficient stability following what may be a relatively small damage."

Model tests on stability of damaged but still functional ships suggested a 0.5 probability of survival for 30 minutes in a given sea state, the UK said. "In model tests times to capsize have regularly been witnessed beyond this nominal cut-off time; consequently there can be no guarantee of survival, let alone maintaining the capability of returning to port, beyond 30 minutes. It is now a requirement that essential equipment must remain operational until successful return to port, which may take considerably longer than 30 minutes."

In another submission, the UK said that SOLAS 2009 had abandoned the margin line, permitting flooding of the bulkhead deck right up to evacuation routes or down flooding points and "may rely on partial watertight bulkheads or webs for progressive flooding to be controlled. Reliance on these partial watertight bulkheads or webs to be effective in preventing either the flooding of evacuation routes or progressive flooding in anything other than still water is unjustifiably optimistic".

A further submission suggested that no watertight doors should be allowed to remain open while the ship was operating in hazardous conditions and there should be more control on leaving them open in less hazardous conditions.

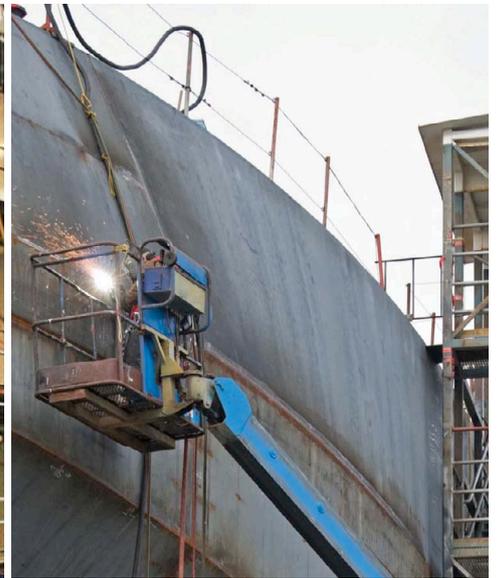
Land-based industries the UK suggested have a significantly lower tolerance of risk than is the case in the maritime industry. "If regulators are to have confidence in the safety levels that the marine industry is prescribed to operate within, then the levels should be comparable to those demanded by governments of industries involved in activities which give rise to the opportunity of a similar number of fatalities. They should also have confidence in the methods by which the levels are established." NA



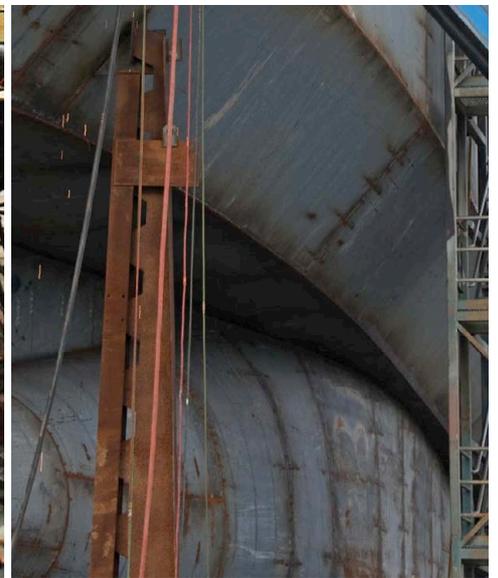
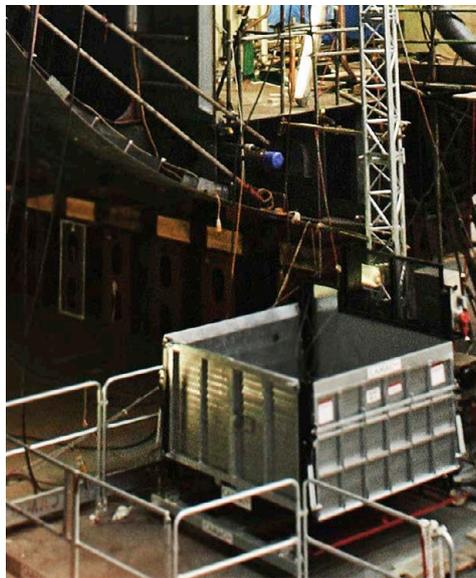
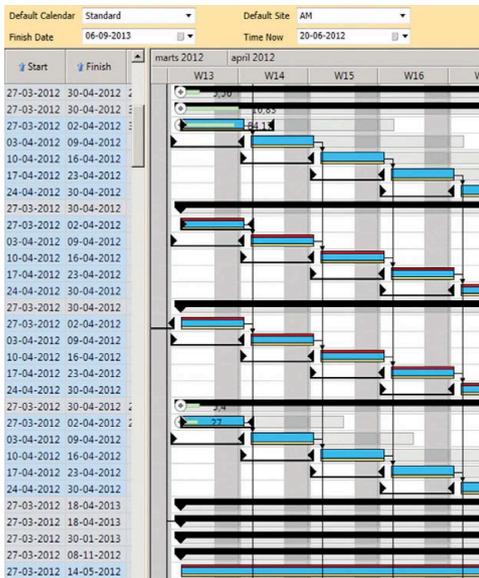
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## Bridge systems

## Costamare installs Transas simulators

Transas Hellas supplied a navigational simulator complex to Costamare Maritime Training Services S.A in Athens.

The simulator complex consists of a Transas full mission bridge simulator NTPRO 5000 latest version with 240deg visualisation, ECDIS Class and Debriefing Area. The full mission bridge will be used for training and certification of watch officers and chief officers in ship handling. ECDIS class will enable Costamare Maritime Training Services to carry out conventional ECDIS training and issue certificates of competency in full compliance with STCW 2010.



Full mission bridge simulator NTPRO 5000 at Costamare Maritime Training Services

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[www.transas.com](http://www.transas.com)

## CAD/CAM

## ShipConstructor launches 2013

Canada-based ShipConstructor has launched its latest version of its software ShipConstructor 2013. The software will offer its users 33 new features and 194 additional improvements including its latest solution for design reuse as well as an extension of the ShipConstructor Associative DWG technology regarding BOM Revisioning.

ShipConstructor 2013 is compatible with AutoCAD 2013. Since ShipConstructor has an AutoCAD platform and is an Autodesk partner product, this means that the latest feature set in AutoCAD are now available within the ShipConstructor software.

[www.shipconstructor.com](http://www.shipconstructor.com)

## Propulsion

## MJP Waterjets acquires Ultra Dynamics

MJP Waterjets has announced the recent acquisition of Ultra Dynamics. MJP Waterjets and Ultra Dynamics will become even more present in the marine market and will be able to offer more products in the near future, highlighted both companies. The group will jointly work on research and development in order to further strengthen both product lines and enhance the combined company's portfolio.

Redeye and KPMG acted as financial advisors and Andulf Advokat and McGuire Woods as legal advisors to MJP Waterjets and Verdane Capital in this transaction.

[www.mjp.se](http://www.mjp.se)

## Ancillary equipment

## Dyena's health check

Dyena has launched its Acceleration Recorder that has been specifically designed for operators to increase the safety of the crew and reduce the risk from chronic injuries associated with operating in harsh environments and to assist them in complying with the latest EU Directives on exposure to shock and vibration.

Shock-loads are recorded alongside GPS data such as position, speed, heading and time. The data is presented on a 3D map display making it the most useful and easy to understand method seen in any data logger system so far.

The Dyena Acceleration Recorder also has other features that allow fleet managers to keep an eye on their vessels; for example monitoring of the condition of their vessels which, will allow them to be better informed when they may need attention from use in rough conditions.

The Acceleration Recorder can also provide a health surveillance system. In the event of an accident, the recorded data can be used to substantiate circumstances and events.

[www.dyena.com](http://www.dyena.com)

## Ancillary equipment

## Martek monitors for gas

Martek Marine has released Marine Tankscape, its latest gas monitoring system for tankers and reefer vessels, by producing a certificate for Port State Control and other inspectors as well as storing the information for download.

The Marine Tankscape system incorporates seven instruments for confined space and cargo monitoring and inert gases into one instrument and allows up to five gases to be measured and displayed at the same time.

# LNG Bunkering: GTT Solutions



In the short term, the release of polluting exhaust gases ( $SO_x$ ,  $NO_x$ ,  $CO_2$ ) will be restricted.

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Marine Tankscape can detect oxygen, hydrogen sulphide, carbon dioxide and carbon monoxide levels. The hydrocarbon range, which uses infrared technology for inerting and purging operations, can be calibrated with butane, propane or methane gases.

The Marine Tankscape also comes complete with a suite of application software. The software gives ease of use for onboard calibration and provides the ability to print calibration certificates, highlights Martek. In addition, complete data-logging software comes as standard allowing logged gas readings, with vessel locations, to be uploaded to a PC. The system also has ATEX and MED approval.

[www.martek-marine.com](http://www.martek-marine.com)

#### Ancillary equipment

## PSM extends range

PSM Instrumentation's range of mechanical marine float level switches has now been extended to include replacement solutions for its Mobrey products that fail in service. Mechanical float level switches are amongst the most widely used, level products in marine tank level measurement and pump control, highlights PSM. The newest additions to the company's KD series provide a practical replacement alternative, especially where original products may now be difficult to obtain due to obsolescence or cost issues.

With options to cover all common construction options, also including the Mobrey "A Pattern Square Flange", the KD series offers better availability. With a rugged construction suitable for extreme marine environments, PSM's KD series mechanical float level switches will be capable of meeting these demands and, in addition, are approved and certificated for marine applications by many of the global type approval organisations as well as hazardous use by ATEX EEXd.

[www.psmmarine.com](http://www.psmmarine.com)

#### Performance monitoring

## Marorka performs online

The Marorka Online team has implemented the functionality required to reliably and transparently measure hull and propeller performance in their 'energy-management dashboard'.

The functionality in the Marorka Online solution is fully compatible with Jotun's Hull Performance Measurement Method (JHPMM), which was developed specifically to enable performance-based contracts as part of Jotun HPS. JHPMM has been placed in the public domain. The Marorka Online platform can be used to reliably determine the outcome of performance-based contracts between shipowners and suppliers of hull and propeller performance solutions.

According to Marorka's Director of sales and marketing, Kristinn Aspelund: "There is an increasing body of

evidence as to the fuel-cost and GHG-emissions saving potential related to improvements in hull and propeller performance. Enabling reliable measurements of hull and propeller performance through Marorka Online is an important step in our continuous efforts to help the shipping industry become more energy efficient, more sustainable and more competitive."

[www.marorka.com](http://www.marorka.com)

#### Deck equipment

## MacGregor equips Korean yards

Cargotec will supply MacGregor ro-ro access equipment for two 3,500 container equivalent units (CEU) Neptune Line PCTCs, ensuring reliable operations and fast port turnaround times.

Cargotec will supply each vessel with an axial stern ramp/door, a quarter ramp/door, two rampway doors, a movable flap and a liftable car deck, along with pilot and bunker doors and a power pack.

[www.cargotec.com](http://www.cargotec.com)

#### Ancillary equipment

## Alfa Laval launches AlfaNova M HP 400

Alfa Laval has announced the launch of its gasket-free, 100% stainless steel AlfaNova M HP 400 plate heat exchanger for use as cargo condenser and/or heater aboard liquid petroleum gas (LPG) carriers. A compact, lightweight alternative to traditional shell-and-tube heat exchangers, the AlfaNova M HP 400 will assist the shipowner in meeting the requirements of the Chemical Distribution Institute's "Ship Inspection Report for Chemical and Gas Tankers," seventh edition. It also provides shipowners with the benefits of higher efficiency, increased safety, greater temperature flexibility, and lower total cost of ownership, claims the company.

With the introduction of the AlfaNova M HP 400 to the maritime industry, it provides the LPG market with the option of using an indirect system instead of using shell-and-tube or welded-type condensers.

"We have adapted the proven fusion-bonded AlfaNova heat exchangers to the cargo conditioning requirements of LPGs," says Johan Lennartsson, Alfa Laval Marine & Diesel's regional marketing manager. "By combining an innovative 100% stainless steel brazing filler and patented fusion technology, AlfaFusion, in a compact heat exchanger, we are able to provide an ideal cargo condenser for indirect LPG reliquefaction systems. The AlfaNova M HP 400 has the same low weight and high efficiency as a copper brazed plate heat exchanger but is suitable for all LPG media including ammonia." **NA**

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# Innovation key in meeting future challenges

Shell Alexia S4 and oil stress technology helps deliver innovation advantage for the shipping industry writes Jerry Hammett, Marine Technology Group Manager, Shell Global Solutions, in response to criticisms levelled at wide range lube oils that also have a medium range BN value of between BN50-60

**R**ecent reports in the media have called into question whether or not the so called 'mid-range' cylinder oils such as Shell Alexia S4, have a place given current operational conditions in the shipping industry. Shell believes that they most certainly do. Our rigorous testing has demonstrated that the performance of a cylinder oil is not easily equated to their final BN - when formulated with sound science, such products can deliver better results in comparison to conventional BN70 oils.

The most important factor is oil stress. Understanding oil stress is key to developing a new product. If you know exactly how an oil degrades in service, then you know how to build something better. One of the notable outcomes of the work to develop Shell Alexia S4 has been the recognition that equating performance of a product to its BN number may be too simplistic. This has been clearly demonstrated in both laboratory engine tests and field trials<sup>1</sup>, where Shell Alexia S4 has outperformed Shell Alexia 50 and other key competitor 70BN products.

The assumption that performance can directly be equated only to a BN number is being challenged by the results we see from the field with Shell Alexia S4<sup>2</sup>. By utilising additives in our formulation to tackle different aspects of oil stress we have seen that innovation is possible and indeed a very necessary step forward - not only for Shell Alexia S4, but also as a foundation for future products.

The development of Shell's wide range lube oil was a direct response to feedback from our customers about the major challenges that the shipping industry is faced with, such as weak charter rates and rising costs, more stringent emission regulations, increased use of slow steaming and the marine industry's desire to lower oil feedrate. Alexia S4 was developed



Shell's Hamburg-based Jerry Hammett says that oil stress is more important than BN number in the evaluation of lube oil performance

and trialled under the most challenging conditions that we could find, which included rigorous testing under slow, ultra slow and flexible steaming.

The field trials of Alexia S4 have resulted in original engine manufacturers giving 'no objection letters'. In its development and field experience the wide range lube oil has been shown to improve engine wear protection, which can reduce maintenance; promote simplicity and serve as a foundation for optimised oil feed rates. In many cases, it can also simplify operations and help cost reduction

We are confident Shell's latest product has demonstrated performance and our studies in oil stress technology will help to deliver innovation advantage to the shipping industry. Time will show that the key performance measure is not 'how much' BN, but rather 'what BN' and how well the oil is able to spread inside the engine. In time, we feel that products that are focused on controlling all aspects of oil stress will become the new industry standard. **NA**

**Footnote:**

1. Shell Alexia S4 was tested across a wide range of fuel specifications (0.5 -3.5% sulphur content) and across a wide range of operating conditions, from the Antarctic to the Suez Canal- to the Amazon.



Shell Marine Products says it goes beyond the sulphur-BN relationship and considers oil stress in the engines while developing its products



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- NAVAL ARCHITECTURE AND SHIP DESIGN EDUCATION IN SINGAPORE AND NEWCASTLE: UNDER-GRADUATE LEARNING AND TEACHING THROUGH TO INITIAL PROFESSIONAL DEVELOPMENT. *P N H Wright, J Downes, Newcastle University, K W Hutchinson, Babcock Int., UK*
- GRADUATE ATTRIBUTES: INDUSTRY AND GRADUATE PERCEPTIONS *Mark Symes, Giles Thomas and Dev Ranmuthugala, Australian Maritime College, University of Tasmania, Australia*
- MY REFLECTIONS: FROM A SHIPYARD TO A CLASSROOM *A K Dev, Senior Lecturer, School of Marine Science and Technology, Newcastle University, Singapore*
- THE ANALYSIS OF SOME NEW AND OLD REQUIREMENTS OF THE INTERNATIONAL MARITIME CONVENTIONS. *Oleksandr Kanifolskyi, Odessa National Maritime University, Ukraine*
- COLLABORATIVE WORK BETWEEN I.T.S. AND PT MERATUS LINE, AN EXAMPLE OF SUCCESS STORY OF TRIPLE-HELIX APPLICATION IN MARITIME INDUSTRY IN INDONESIA *I K A P Utama, Institut Teknologi Sepuluh Nopember (ITS), Surabaya, Indonesia & J R Pramadi, PT Meratus Line, Surabaya, Indonesia*
- INDIA AS THE HUB OF MARITIME TECHNOLOGY EDUCATION IN SOUTH EAST ASIA. *P Viswanath, Synergy Marine, V Shankararaman, Singapore Management University, Singapore, S Kodungallur, Cochin University of Science and Technology, India*

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# MAN clarifies its universal lubes position

Lubrication of marine diesels has become a significant issue since Castrol flagged the potential risks of using a, so-called, universal oil, earlier this year. As a result engine manufacturer MAN Diesel & Turbo has found it necessary to issue service letters to clarify its position

The world's largest engine manufacturer MAN Diesel & Turbo has moved to clarify its position on the use of a single oil solution for slow steaming ships that operate both inside and outside of emission control areas (ECA).

In a series of three service letters to its clients MAN has reassured clients that universal lubricants are effective in all its engines except the latest Mk 9 and G-Type engines.

"Some oil companies have, in order to simplify operations of large two strokes, developed a single lube oil that gets away from the two lube solution," said MAN director of promotions and sales Otto Winkel. "Oils developed in the range of [base number] BN50-BN60 have been tested by MAN and the performance is fine," he added.

He went on to say that the Mk 9 and G Type engines have a higher pressure within the cylinder and that these engines could suffer from "cold corrosion" on the cylinder walls. "The Mk 9 was tested and was subject to heavy corrosion." He went on to say that while the G Type engines have not been tested they are of a similar design to the Mk 9 and MAN believes they will suffer the same cold corrosion.

Winkel went on to emphasise that universal lube oils were fine for a significant proportion of the manufacturer's engines that are operational today, up to the Mk 8 designs. "With the majority of engines in service these [universal] oils work beautifully." Pressed on whether this would be the case for more than 90% of current engines he says: "I would agree with that".

MAN sent out its service letters to clients following claims by Castrol that universal lubes were damaging engines. According to Castrol the potential damage of using a universal lubricant could be severe and the marine lube oil producer has taken it upon itself to warn users of the potential dangers that the use of the new oils could pose.

The latest oils offer a single solution to owners whose ships may operate both inside

and outside of ECAs, where fuel inside the ECA will have a low sulphur content, whereas bunkers used outside the ECA regions can have up to 3.5% sulphur content, or 5% if a scrubber is fitted.

Rather than having to carry two grades of oil and switching as your vessel approaches the ECA area Total's Talusia Universal, Shell's Alexia S4 and ExxonMobil's Mobilguard 560VS will allow owners to store a single lube oil for use with fuel that can range from 0.5% to over 3.5% sulphur content.

Castrol's view is that these oils have a mid-range BN value from 57-60, and that this is too low for vessels operating outside of ECA areas, which they say requires a lube oil of around BN70. When ships enter the ECA area Castrol believe that a lube of BN40 is sufficient, particularly when slow steaming. On the one hand the lower BN outside of the ECA will mean that corrosion from calcium deposits will occur and inside the ECA the engines will suffer from too many additives.

In both cases the result is excessive wear on the cylinder walls which can be costly.

Paul Harrold, technology manager marine & energy lubricants at Castrol said earlier this year that "ideally shipping companies would prefer only to have to use one cylinder oil that would work with a variety of different sulphur fuels, but recent engine inspections suggest that the desire for simplicity may be compromising reliability and damaging to the engine, particularly under slow steaming conditions."

In addition Castrol said that the balance between fuel sulphur levels, cylinder oil feed rates and BN values will become more complicated when a vessel is slow steaming and in order to ensure that corrosion is minimised a range of lubricants is the most cost effective solution. "A two dimensional problem has evolved into a three dimensional problem" said Castrol.

"We have field evidence that slow steaming is leading to corrosive wear when lower BN

lubricants are used with relatively high sulphur fuels," says Harrold.

Initial comments from Castrol were clearly aimed at Total's Talusia Universal which, for some years was the only wide range lube oil on the market. To which Total Lubmarine has put up a stout defence of its product.

Jean-Philippe Roman, technical director, Total Lubmarine told *The Naval Architect*: "We are concerned about the biased interpretation [by Castrol] of MAN's recently issued customer service letters. These detailed technical documents contain recommendations for both existing engines, which currently represent approximately 99% of the marketplace, as well as the engines of tomorrow. It clearly states that single oil solutions are approved for all engines except for Mark 9 and G series, which cannot be recommended "at present".

In its latest press announcement Castrol says: "Some cylinder lube oil suppliers have suggested that a single mid-range BN cylinder oil is sufficient for use with all marine fuels, under all operating circumstances. Castrol believes that customers faced with the prospect of only one grade of cylinder oil to cover all operating scenarios may be putting themselves at a disadvantage, especially if they regularly use fuel at the upper and lower ends of the permitted sulphur spectrum.

Castrol added: "MAN states: "The design philosophy of two distinct lube oils is based on observations and tests showing that over-lubrication leads to over-additivation with consequential risk of calcium deposit formation and total suppression of corrosion, decreasing the scuffing tolerance. Moreover, under-lubrication may lead to under-additivation, which will lead to corrosive wear in cylinder liners and piston rings."

Roman countered that: "Total Lubmarine respects the views of those that subscribe to conventional thinking; that cylinder oil should have a BN that matches the sulphur content of the fuel. With several

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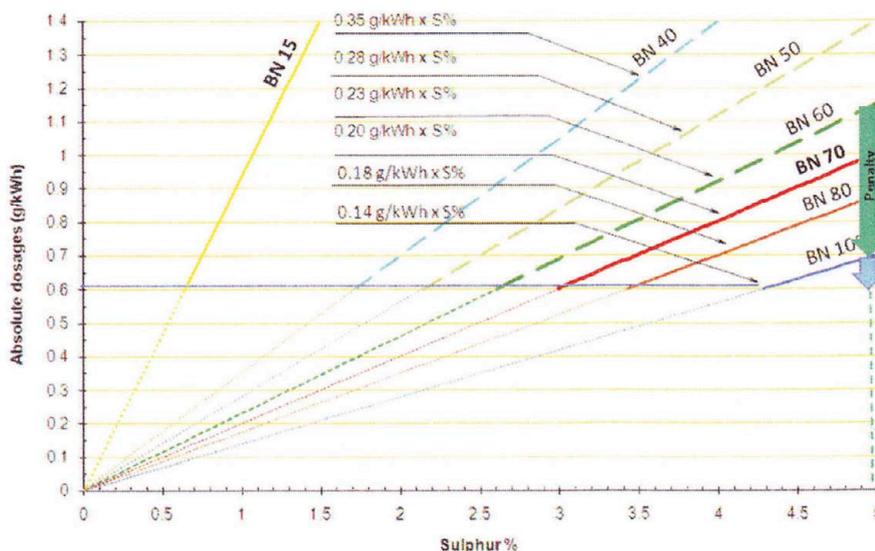
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ACC Cylinder Lubrication, feed rate factor as function of BN

relatively unproven so called single oil solution products recently launched to the marketplace, claiming to match the benchmark set by Total Lubmarine in 2008, we appreciate why this has caused some confusion. Five years of hard, corroborated evidence dictates that it is misleading to categorise lubricants simply according to their basicity - 'mid-range' certainly does not automatically equate to 'universal' or 'single oil solution.'

And Winkel appeared to support Total's view, although he would not name individual oil companies, he told *The Naval Architect*: "The single solution oils passed all the tests, they're very good oils."

Although, Winkel did say that feed rates for the single oil solutions may be higher and MAN has produced a table (see above) that shows the required feed



rates for various lubricants in differing circumstances. Meanwhile, after defending Talusia Universal Total's Roman looked further ahead: "The impending new challenges presented by 2015, 2020

and beyond come as no surprise – and more will ensue. Changing regulations, decreasing sulphur caps and altered operating conditions have, for some time, driven new engine types and designs." **NA**

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# Meeting the EEDI Challenge: Fostering growth through R&D

Good operation and low fuel consumption are the basic requirements of the regulations for energy efficient ships passed by IMO for ship designs. Starting this year ships that do not comply with the EEDI (Energy Efficiency Design Index) requirements will be eliminated or upgraded eventually. Liu Ying Reports

In July 2011 the IMO adopted the amendments to MARPOL Annex VI stipulating that regulations on energy efficiency for ships will come into effect on 1 January 2013. At that time [2011], most of the ship models in China did not meet the EEDI standard and were expected to be ousted, or would need to be upgraded to fulfill the new requirements.

The whole of the country's shipbuilding sector has been hugely stressed as 2013 approaches. Some shipbuilders had even hoped that China, as one of the parties to the MARPOL Annex VI, could push the implementation of EEDI back by four more years.

Nevertheless, at an industry forum held not long ago, the Shanghai Society of Naval Architects and Ocean Engineers (SSNAME)'s chief executive Zhang Sheng Kun said the China shipbuilding sector had decided not to fight for more time and will adopt EEDI standards as required in 2013.

How, in this short period of time - within a year - the shipbuilding sector in China could have such dramatic change in attitude towards EEDI? Are Chinese shipyards ready to meet the EEDI challenge?

In fact, many industry experts are of the opinion that postponing the implementation of EEDI would only hinder the industry's development. In the extraordinarily competitive newbuilding market, Chinese shipyards have to face the EEDI challenge head-on in order to survive and to grow.

Not only that, China has already built up the foundation to meet the EEDI requirements. As a matter of fact, shipbuilders in China started the corresponding studies back in 2011, before EEDI had become official. Now, many shipbuilding companies have already finished upgrading their major ship models so they can meet the EEDI standards. China has also launched

related industry standards and policies to encourage shipbuilding enterprises to raise their competitiveness and strive for larger room for development.

## Prompt reactions rewarded

At the beginning of 2009, an IMO reacting mechanism leadership group was set up in China, whose members included representatives from the Ministry of Industry and Information Technology, the Ministry of Transport, the China Association of The National Shipbuilding Industry, the China Society of Naval Architects and Marine Engineers (CSNAME), the China Classification Society, the China State Shipbuilding Corporation and China Shipbuilding Industry Corporation.

There were five expert units to react to different IMO regulations under the leadership group, including an EEDI expert unit.

The unit conducted research and analysis of ship model data in China and

Sinopacific Shipbuilding's Crown 63 bulk carrier meets the EEDI stage two requirements



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compared them with the EEDI standards, and then explained and promoted the EEDI documents to the shipbuilding industry. It also helped enterprises on their researches of energy saving and emission reduction technology and their development of green ship models. China has made big strides in preparing for the implementation of EEDI thanks to the leadership group.

According to the three-stage implementation requirements of EEDI, an efficiency improvement of 10% is required for vessels of the size of 400gt or more running on international routes in 2015-2019; an efficiency improvement of 20% is required for such vessels between 2020 and 2024; and an efficiency improvement of 30% is required for these vessels from 2025 onwards.

In order to meet the EEDI requirements, the shipbuilding sector has focused on the development of energy saving and emission reduction designs and technologies in recent years, including designs for low resistance ship hull shapes; light ship body structures; highly efficient turbines; applications of energy saving and emission reduction equipment; ship designs that require reduced ballast water; ways to re-use waste heat energy; applications of light materials, automatic energy consumption management systems, low emission hybrid engines; and the evaluations and empirical studies of energy saving and emission reduction technologies onboard.

Meanwhile, CSNAME has kicked off the development of low-carbon ships with the help of a group of industry experts and has launched a series of new ship models in

2012. With the same speed and loading, the new ship models of 110,000tonnes or below achieve an efficiency improvement of 20% compared to their corresponding models previously in the market; while those of 110,000tonnes or more achieve an efficiency improvement of 10%.

### Models that meet EEDI requirements

The major shipyards in China have eagerly worked on the development of green ship models. Since the concept of EEDI was conceived among the international marine community in 2008, some well-known shipyards in China started upgrading their products.

Shipyards such as: Shanghai Waigaoqiao Shipbuilding Co Ltd, Hudong-Zhonghua Shipbuilding (Group) Company Limited, Guangzhou Shipyard International Company Limited (GSI), Dalian Shipbuilding Industry Company Limited (DSIC), CSC Jinling Shipyard, Jiangsu Rongsheng Heavy Industries Company Limited and Sinopacific Shipbuilding Group etc. have launched numerous ship models of their three major ship types that fulfil EEDI requirements.

These ship models have been well-received by the market. Shanghai Waigaoqiao, Jiangsu Rongsheng and Sinopacific Shipbuilding have received large orders for some of their new models.

Among all the new models, the 206,000dwt bulk carrier developed by Shanghai Waigaoqiao has an EEDI of 2.55, 9% lower than the prescribed 2.81

base line. The EEDI of the latest model of 208,000dwt bulk carrier of Shanghai Waigaoqiao even reaches 2.32, which is 17.5% lower than the base line.

Moreover, the yard's 318,000dwt VLCC (see image below) has an EEDI that is 15.7% lower than the base line; with the heat recycling system installed, this model's EEDI can be 19.27% lower than the base line. Recently, the company also launched a 321,000dwt VLCC model and a 300,000dwt VLCC model.

The VLCCs have optimised bow and stern shapes and are equipped with longer turbines and derated G-type engines. These design details and equipment help reduce the vessel's oil consumption by 30%. The EEDI of the two models are at least 20% lower than the base line.

Meanwhile, Hudong-Zhonghua Shipbuilding has developed a 10,000TEU-plus containership model that matches the EEDI requirements. The yard was building four 10,036TEU self-designed boxships, with a length of 335m and a 48.6m beam, that consume 30% less diesel than similar containership models. Those vessels' EEDI is 30% lower than the prescribed base line which means they already fulfil the EEDI stage three requirements.

GSI's 50,500tonne and 39,000tonne oil tankers already meet the EEDI stage one requirement. The yard has launched models of 50,000tonne and 37,500tonne chemical/product tankers in 2011 which meet the EEDI stage three requirements.

DSIC have started to develop new models of 320,000dwt oil tanker, 110,000dwt Aframax product tanker, 159,000dwt Suezmax tanker in 2009, and managed to lower the EEDI of all three ship types.

Among mid-sized shipyards, Taingjin Xingang Shipbuilding Heavy Industry Company Limited has built the new-generation 40,000dwt bulker for a French owner. The ship's daily fuel consumption has been lowered to 18tonnes from 31.2tonnes, and its EEDI has also been lowered by 17.8%.



A 318,000dwt VLCC designed by Shanghai Waigaoqiao Shipbuilding Co Ltd attained an Energy Efficiency Design Index (EEDI) below the prescribed base line

In July, another mid-sized yard, CSC Jinling Shipyard won an order for four 64,000dwt bulk carriers. The yard reduced the vessels' EEDI to 3.75, which fulfils the EEDI stage two requirements, through ship hull shape optimisation and the use of the G-type engine.

Privately-run shipyards in China are also advancing in green ship model development. Jiangsu Rongsheng has lowered the EEDI of its 76,000dwt Type-4 bulker, its 156,000dwt bulker, its 6,600TEU containership and its 400,000dwt iron ore carrier by 17.4%, 12.4%, 42.7% and 13.4% respectively.

Furthermore, Sinopacific Shipbuilding's Crown 63 green bulk carrier is able to achieve an efficiency improvement of 20%, which is enough to meet the EEDI stage two requirements, and received an EEDI certificate from Bureau Veritas in March this year.

Apart from shipbuilding enterprises, research institutes are also keen to develop green ship models that comply with EEDI requirements. At the Posidonia Exhibition, held in Greece last summer, Shanghai Merchant Ship Design & Research Institute (SDARI), Wärtsilä and Det Norske Veritas (DNV) jointly presented the concept design of Green Dolphin, a 38,000dwt handysize bulk carrier whose daily main engine fuel consumption is 17.7tonnes. It attained an EEDI value of 25% less than the required index set by the IMO reference line for bulk carriers.

Another model of Green Dolphin, a 64,000dwt bulk carrier, has a daily main engine fuel consumption of 17.7tonne and an attained EEDI which is 18% less than the required index.

CSIC's China Ship Design & Research Center Co Ltd has launched its model of *Dunkerque*-max type 180,000dwt capesize bulk carrier, a similar design to its green "Chinese model". The *Dunkerque*-max can satisfy the second stage EEDI requirement and has the potential to be further optimised.

### Encouraging R&D

Since the second half of this year, China has speeded up the drafting of related standards and regulations to help the country's shipbuilding sector cope with the EEDI challenge.

Regarding ship examinations, China Classification Society's (CCS) EEDI Implementation Guidelines came into effect in July and CCS has also announced the "EEDI Evaluation Guidelines for Inland River Vessels" on 30 July providing instruction for the calculation and evaluation of EEDI for river vessels.

With regards to policies and regulations, the Ministry of Transport announced the regulations and examination methods for operating ship's fuel consumption and CO<sub>2</sub> emission in June, which would become effective in September.

In late August, five national standards drafted by experts from the Ministry of Industry and Information Technology, including ships' EEDI base line, the calculation method for EEDI, examination method of ships' EEDI, examination method for the proportion of usage of new energy for LNG-diesel hybrid vessels, speed and efficiency evaluation guidelines for ships and marine technology have all been passed.

The first three standards have set the base lines, calculation and examination methods of EEDI for 12 types of ocean-going vessels and six kinds of inland river ships. The latter two provided guidelines on the applications of the examination methods of EEDI together with vessel speed testing analysis.

It is understood that the above mentioned standards are all in line with IMO and class society requirements. The IMO's method of calculating EEDI has been directly adopted as the recommended national standards to be approved and announced.

Experts in the sector said that the use of new energy or highly-efficient vessels will lead to tax reductions according to the Regulation on the Implementation of the Vehicle and Vessel Tax Law of the People's Republic of China, which came into effect in January this year. The above standards have provided technical references for the evaluation of green ships and new energy vessels, encouraging the shipbuilding sector to react promptly to EEDI. **NA**

Privately-run shipyards in China such as this one in Rongsheng are developing their ship designs so that they meet new EEDI requirements



# Streamlining project makes efficiency gains

Up to 90% of all goods traded by Europe are transported by sea. Increasing environmental concerns, borne out in new legislation, coupled with volatile oil prices, have created a renewed focus on fuel efficiency. The STREAMLINE project developers, led by Rolls Royce report

There has been little real change in the state-of-the-art for conventional screw propeller propulsion for many years with only a marginal rate of improvement during the last 50 years. More substantial progress has been achieved through the use of better propulsor configurations and improved integration of the propeller with the vessel hull hydrodynamics.

As has previously been reported there are no less than eight R&D projects addressing energy efficiency and environmental aspects within the EU's 7th Framework programme's Sustainable Surface Transport Programme. STREAMLINE - Strategic REsearch for InnovAtive Marine PropuLsIoN ConcEpts ([www.streamline-project.eu](http://www.streamline-project.eu)) is a €10.9million programme led by Rolls-Royce, focussing on propulsion. Through the development of advanced CFD techniques and radical new concepts the programme aims to deliver technology for a step change in vessel efficiency.

The project consortium has 21 partners across the EU and is built to comprehensively cover the topics of ship propulsion. Savings here have a large effect on overall vessel efficiency since they are the key interface to transfer power into vessel motion.

This article forms part of the series focussing in on projects that are part of GreenSEE Net (Green Ship Energy Efficiency Network) a gathering of EU FP7 funded projects with a common focus. It will describe the work to date on some of the radical technology concepts for propulsion.

Results of optimisation of state-of-art screw propulsion based on advanced CFD and numerical optimisation tools developed within the project will be also presented. A forthcoming article will focus on these CFD and numerical optimisation methods.

Advancements with respect to standard design tools will be described through examples of numerical applications. The impact of new modelling capabilities to enhance the hydrodynamic performance of ship propulsion will be discussed.

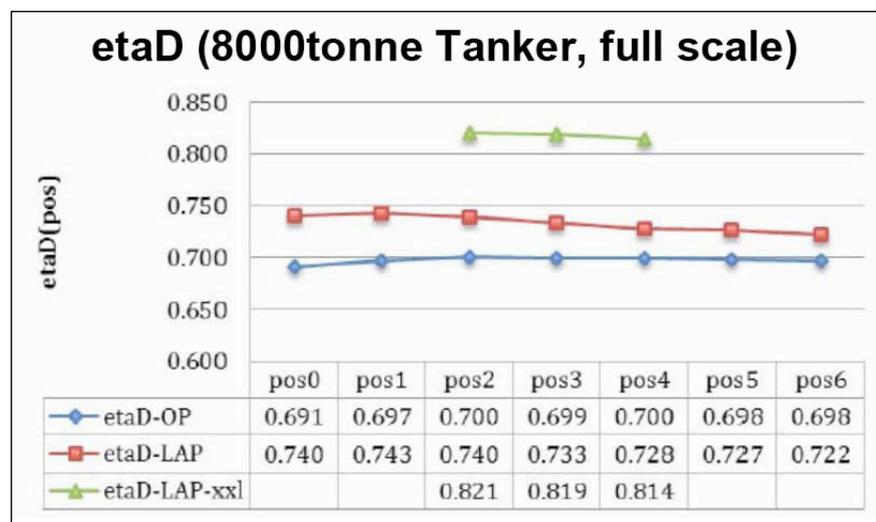
## Large Area Propeller

The Large Area Propeller work package is investigating the concept of a large diameter propeller positioned behind the ship, with the propeller disc in the crest of the stern wave. In order to enable largest possible propeller diameter, the propeller is also allowed to go below the baseline of the vessel. The aft positioning of the propeller, behind the transom of the vessel reduces the risk for high pressure pulse and vibration levels, but increases the risk of ventilation and thrust loss in heavy seas. A significant efficiency gain is achieved due to the larger diameter and lower propeller loading whilst interaction effects are getting slightly worse. The total propulsive efficiency is increased

by some 15%.

The concept is investigated for three different hull types, an 8000dwt tanker, a medium size tanker and a twin skeg ro-ro. The 8000dwt tanker, which has shown the largest potential gain, is taken further to a full system optimisation using CFD, including propeller position and geometry as well as hull geometry modifications. The propeller is moved aft from its original position, diameter is made larger and the effect on propeller efficiency, interaction effects and total propulsive efficiency are being studied. Simulations are being made at Chalmers University, at both model-scale and at full-scale and the results are benchmarked against model tests. Results of propeller efficiency and propulsive factors are being compared. Generally it can be said that the propeller efficiency is increased significantly due to the larger diameter whilst hull interaction effects are reduced with further distance backwards. The optimal solution is compared to the baseline alternative and

Figure 1: Variation of propulsive efficiency with propeller position. Large Area Propeller (red), Original Propeller (blue) and Large Area Propeller extra large



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improvements are being verified by means of further model tests at SSPA. Indications of improvements in the 15-20% range are seen so far.

The larger diameter and its aft position with the propeller tips closer to the water surface than normal increases the risk of ventilation, thrust loss and dynamical forces as a result of that. The risk of ventilation is being assessed by means of sea-keeping tests, conducted by SSPA and CFD simulations. With the propeller so far to stern, manoeuvrability presents a configuration challenge. Under investigation is a separate rudder located behind the propeller or the large area propeller being mounted on a thruster unit. Propeller cavitation performance is being assessed by means of cavitation tests.

The results of investigations made so far indicate that significant efficiency improvements and fuel consumption reductions can be achieved with this kind of concept. Several practical limitations exist, the propeller is penetrating the baseline, the propeller and rudder is located behind the vessels transom etc. This can be a limitation when the vessel is entering harbour and different solutions to solve this problem are to be studied during the remaining period of the project.

### Walvistaart POD

The Walvistaart POD is another of the radical technologies under investigation under the STREAMLINE banner. Initially aimed at inland waterways, the system aims to replicate the highly efficient motion of a whale tail.

Whilst this is a completely new concept in the Marine world, the Walvistaart POD story actually has quite some history. In the mid 1990s the concept for the blade motion was first developed by Prof. Dr. Ir. J.D. van Manen; a Dutch naval architect who for many years was the President of the Maritime Research Institute Netherlands (MARIN), in Wageningen.

Through his innovations in the field of propellers and his pioneering work in respect of cavitation van Manen acquired great fame both at home and abroad and after his retirement he put most of his energy into his invention; a new propulsion system with continuously adjustable blades. Although some of the concepts look similar to other propulsion systems, the motion of the blades through the water is unique to the industry.

In the year 2000 a group of five Dutch companies formed Walvistaart B.V. with the intention to further develop the system and bring it to market.

Each of the five shareholders had their own agreed task within the consortium Walvistaart BV:

- L.G.J. Wolters Lichtenvoorde BV, engineering and design
- HAGUN BV, management
- Westerkade Shipping BV, ship construction and design
- Verenigde Bierens Bedrijven BV, gears and gearbox specialist
- Van Voorden Gieterij BV, sales and maintenance.

Since the formation of Walvistaart BV in 2000, MARIN have collaborated on a number of studies including a feasibility study on the efficiency, calculations of the blade pattern, losses of the blade pattern, discussions on model tank testing, hydro calculations and calculations on propulsion factors for the POD.

The objective within the STREAMLINE project has been for Walvistaart B.V. to complete design studies on the optimum solution. Once the propulsion unit has been built and installed on the vessel, MARIN will once again be involved, this time to perform real-world performance measurements.

Within the STREAMLINE project MARIN carried out calculations and tests for the hull form designs, which have a very unconventional stern in order to accommodate the novel propulsion system. On the basis of this report the vessel's hull was designed.

### The pod design

Walvistaart B.V. concluded right from the start of their activities that the original wheel design of van Manen was not practical; too massive, too sensitive to breakdowns and therefore unsalable. As a result it was decided that a POD design was more suitable for the inland water vessels the system was originally targeted for.

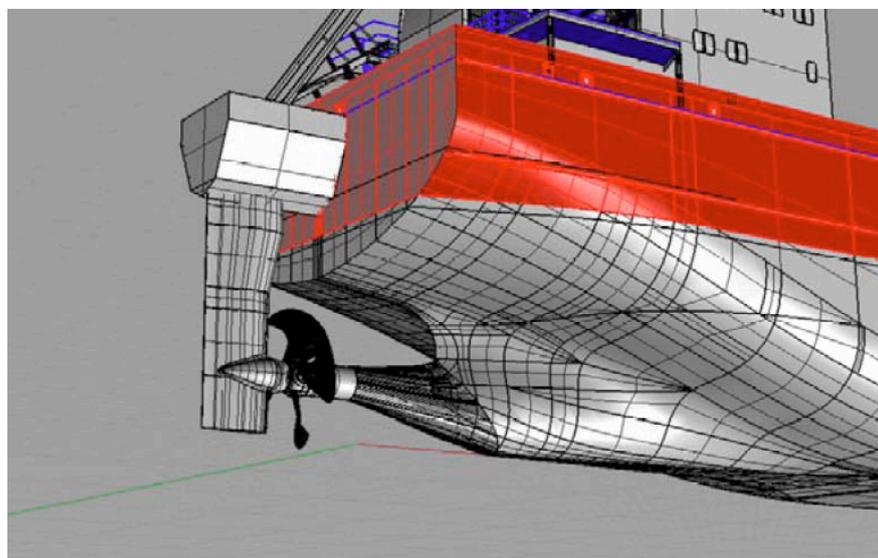
Based on an analysis of their target market, key performance attributes were set for the propulsion system, namely that the propulsion system should:

- a. have a fuel consumption of 30% less than on an equivalent size vessel fitted with a ducted propeller
- b. propel a vessel of dimensions: length 110m, beam 11.45m, depth 5.32m and displacement of approximately 300dwt
- c. have a 10 year service life without breakdowns (50,000 hours)
- d. have been sold (under conditions) before its building starts, for transfer to the user after successful completion of trials.

In the early days of the project MARIN carried out some model tank testing with the original van Manen design and also gained some practical knowledge from the vessel the system was fitted on.

The configuration for the pod that was developed during STREAMLINE consisted

Figure 2: Illustration of the Large Area Propeller concept





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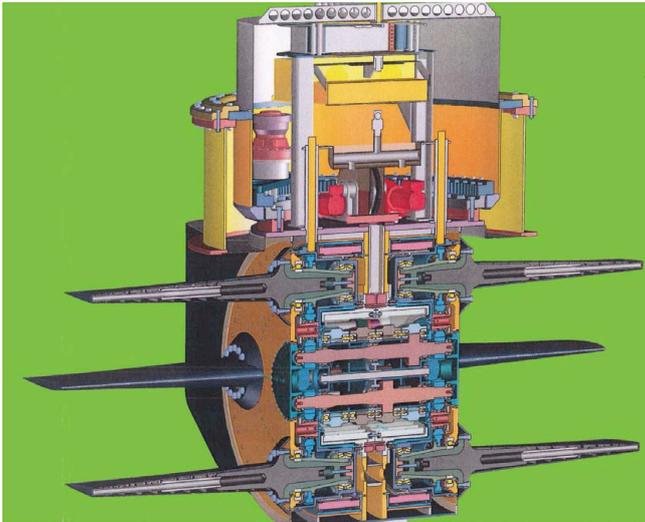
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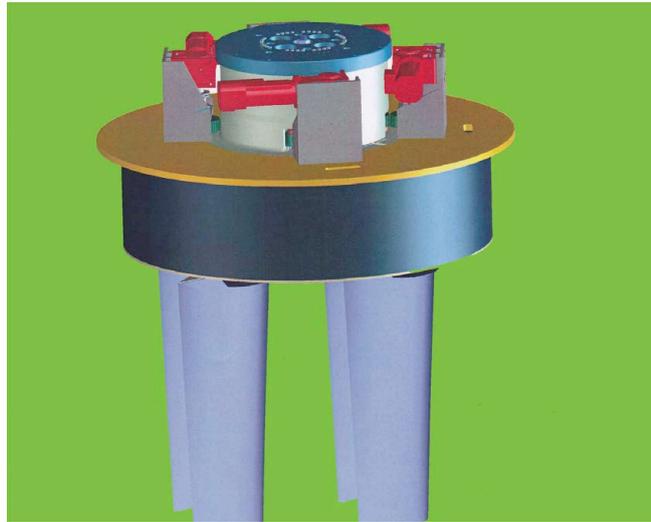
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1,000kW POD (1) horizontal blades



500kW POD (2) vertical blades

of an azimuthing pod with rim-driven electric motors in each side (1). Through an innovative mechanical design, four blades are rotated on each side of the pod and prescribe a specific motion as they go round. This motion generates a net thrust by 'flicking' each blade in turn, mimicking a whale tail.

The major challenge during the design was the required strength of the blades and bearings. Calculations had shown that the blades will snap if the POD (1) was turned more than 90degrees while sailing at a speed of 12km or more. Since extreme rotations are only required for low speed manoeuvring, this limitation was deemed acceptable and a simple control system is used to avoid operation outside of the design range.

At the maximum forward speed of 20km/h, the pod cannot rotate further than 20degs from straight ahead. At speeds below 12km/h, this constraint is removed and full 90degs rotation is permitted.

In order to generate thrust, the power is needed not only for the power wheel to make the circular movement of each blade but also for the spindle axis of each blade to provide a certain angle of attack.

The required thrust of 132kN (for a calm water vessel speed of 20km/h at draught of 3.7m) can be generated by the POD (1) blades with a total delivered power of 1026kW, of which only 60kW is used to articulate the blades and the remaining 966kW drives the main circular motion.

The thrust force per blade in one cycle varies from about -50kN to +120kN while the spindle torque of each blade varies between

-8kNm to +8kNm. This is a significant improvement over the original design and is achieved through careful design of the internal mechanisms.

Throughout the course of the project, the design of the POD has undergone some configuration modifications. The baseline design configuration has four horizontal blades on each side of an azimuthing pod. Compared to a conventional propulsor, the system imparts a small change in velocity to a large volume of water and so is expected to be 30% more efficient.

The down side of this arrangement is that it is not suitable for heavy seas, since the blades would clear the water surface and be subject to extreme loads. Therefore it is only suitable for inland waterways. With a view to expanding the concept's applicability, the design was amended to suit seagoing ships, by taking each half of the azimuthing pod and rotating through 90deg. As a result the propulsion system has evolved into two sets of four vertical blades.

The new configuration is mechanically identical to the horizontal concept and suitable for both inland and seagoing vessels. Further studies are required, however, before the system is ready to be fitted to a seagoing vessel.

### Walvisstaart Pod advantages

The Walvisstaart propulsion system is now ready for construction with detailed design work complete. The novel configuration demonstrates a range of advantages over a conventional ducted propeller arrangement.

Efficiency: 30% fuel burn reduction, 360degs thrust vector for enhanced berth manoeuvring and full ahead to full stop in two seconds.

Availability: Direct drive system is designed to be maintenance free for 10 years of operation. In addition the drive units can be replaced with the vessel floating, as can individual blades.

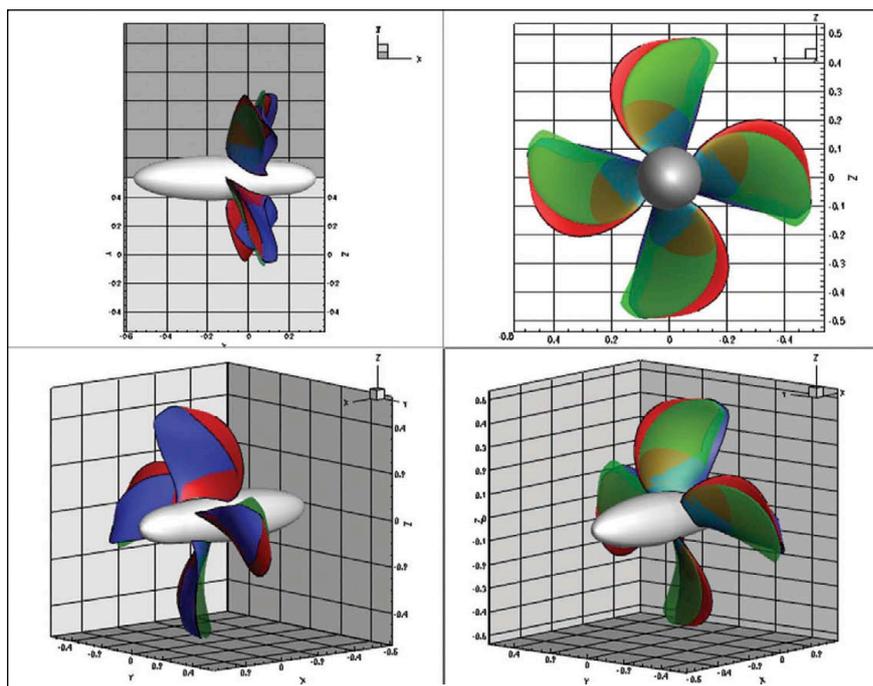
Electric Power System: Since the main drive is now electric, there is much more flexibility for arranging the power systems (no main shaft, main engine or main shaft). Generators can be placed where convenient and the system can be used with any available fuel.

For more details see [www.walvisstaart.nl](http://www.walvisstaart.nl)

### Optimisation of screw propulsion

Radically new propulsion concepts have the potential to provide outstanding improvements of ship hydrodynamic performance through a deep recasting of ship layout and power-train components. For those cases where major deviations from standard design is not possible or simply not customer's advice, stressing the efficiency of conventional propulsion systems is the only viable solution. Retrofitting an aged screw propeller or introducing hull-fitted devices to improve the quality of the hull wake are common examples.

In this context, an important task of the STREAMLINE Project aims at demonstrating the capability of enhanced Computational Fluid-Dynamics (CFD)



Propeller geometry generated by a fully-automated numerical optimisation technique compared to the original design

and numerical optimisation models to provide effective solutions to improve the hydrodynamic efficiency of state-of-art propulsion systems characterised by a conventional screw-propellers. Project partners directly involved are MARIN, HSVA, Chalmers, TUHH, CNRS, FOI, CTO and CNR-INSEAN coordinating the working group.

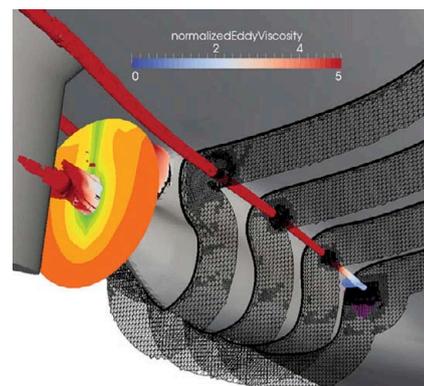
In order to orient design efforts towards applications reflecting real operational requirements, a case study representative of a recently designed 7000dwt single-screw tanker is selected as baseline. A scaled model of the tanker is manufactured and a full characterisation of ship performance through model tests is performed. Results of propeller open water, nominal wake, ship resistance and propulsion, pressure pulses and cavitation tests are collected by a dedicated experimental campaign carried on by partners CTO and CNR-INSEAN. Model test results also provide benchmark data for the validation of CFD models.

CFD-based studies focus on hull and propeller shape optimisation, on the analysis of enhanced propeller-rudder layouts and on inflow improving devices. Suitable objective functions for delivered power and for the wake fraction (Ploeg, 2012) are introduced and design constraints

about ship displacement and minimum hull form slenderness are imposed. The baseline propeller is optimised with respect to efficiency in open water as well as in behind hull conditions. Design constraints to preserve the original propulsion point (power and rotational speed) and the original dimensions (propeller and hub diameter, hull clearance) are given.

The definition of a common design problem allows partners to compare different design and optimisation methodologies. The hull and propeller optimisation approach proposed by MARIN is based on the parameterisation of candidate forms with respect to given sets of available geometries. Parameters defining the target geometry are determined through an optimisation procedure. Viscous-flow predictions of the hull flow including free-surface and propulsion effects are performed by using the RANSE code ReFRESKO, whereas the inviscid-flow solver PROCAL is used to predict propeller performance.

A different optimisation framework based on the so-called free-form deformation technique is proposed by HSVA and INSEAN. This methodology allows the arbitrary manipulation of three-dimensional objects to modify an



Simulation by CFD of the effect of a vortex generator on the velocity distribution at propeller plane

original shape during the optimisation procedure. The methodology is applied to hullform optimisation studies by HSVA whereas the capability to design propellers with unconventional blade layouts was addressed by INSEAN.

Results of hullform optimisations determine delivered power reductions of about 2% or less depending on the importance given to improving hull wake homogeneity. Larger power reductions of 5% and more can be achieved if constraints about the minimum acceptable hull slenderness are reformulated.

Propeller optimisation studies yield open water efficiency gains in the order of 2% by means of the conventional shape obtained via the parametrisation model. Fully-automated optimisation procedures based on the free-form deformation approach determine a 5-6% higher efficiency through rather extreme tip-raked blades. Including behind hull operation in the design project, efficiency typically conflicts with blade pressure constraints to avoid cavitation and improving the efficiency of the original screw by 2% is a hard task.

The analysis of propeller-rudder interactions is the subject of studies carried out by using hybrid RANSE/inviscid-flow models capable of simulating propulsion conditions of the fully appended ship. The replacement of the original full spade rudder with a twisted rudder is investigated by Chalmers. Two different solutions by twisting sections about the rudder leading edge and about the trailing edge are compared. Numerical simulations reveal that twisting the rudder surface

a limited amount (about 1%), delivered power reduction as a result of a partial propeller swirl recovery. More consistent improvements with respect to risk of cavitation and erosion of the rudder surface are achieved.

On the contrary, if the rudder geometry is left unchanged, a sensitivity analysis by HSVA and TUHH shows that original layout optimisation by varying the axial position of the rudder or of the propeller plane yield only minor improvements of hull and propeller efficiency because of limitations to preserve the original layout of the ship aftbody.

Finally, the impact on propeller performance of inflow improving devices is studied. Two alternative pre-swirl stator layouts with three or four fins mounted upstream the propeller disk are analysed by Chalmers. TUHH performed a sensitivity analysis of the optimal positioning of small

vortex generators, whereas HSVA and CNRS presents results for the application of boundary layer ducts on the surface of the hull aftbody to reduce the thickening of the boundary layer imping onto the propeller. All types of inflow improving devices can determine consistent modifications of the velocity field in the hull wake incoming to the propeller. A careful optimisation of the position of such devices is necessary in order to limit the additional drag and the consequent increase of delivered power.

As a general remark, it may be noted that beyond the actual results of design studies, it is demonstrated that advanced CFD and optimisation models provide enhanced propeller design tools by introducing the capability of analysing hull/propeller/rudder interaction at an early stage of design, of investigating through numerical experiments the impact of retrofitting solutions and of exploring potentially

high-performance layouts from fully automated optimisation procedures.

Propeller geometry generated by a fully-automated numerical optimisation technique compared to the original design. Simulation by CFD of the effect of a vortex generator on the velocity distribution at propeller plane. *NA*

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# Calibrating the future

It is unreasonable to expect that the future will herald higher energy prices and greater regulation of shipping's emissions. Adoption of the Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Management Plan (SEEMP) into MARPOL Annex VI moves the industry towards such a future

**U**nderstanding the many components of the "shipping system" can ensure the most robust analysis of economic viability and competitiveness of ship designs both relative to an existing fleet of ships and under possible future regulatory and cost environments.

In describing the development of some of the methods in the Research Council UK (RCUK) project this paper explores 'what if' questions around ship design - taking the perspective that a key challenge for design will be around increased energy efficiency and lower greenhouse gas (GHG) emissions.

A GHG constrained future refers to a future energy costs will be boosted either by increased bunker fuel costs or through regulation that aims to tackle climate change.

Already, a number of future concept designs have emerged. These are hypothetical solutions to a future design specification that limits GHG emissions.

They range from minor modifications to an existing vessel (e.g. Green Ship of the Future) to more radical zero carbon designs, such as NYK's 'Super Eco Ship 2030'.

The RCUK Energy funded research project "Low Carbon Shipping - A Systems Approach" started in 2010 with the aim of understanding the many components of the shipping system to explore how the shipping industry might respond to the challenge of GHG constraints from a combination of the technological, economic, logistical, operational and infrastructure perspectives.

Many of the concept designs produced to date have either focused on the maximum practical reduction of emissions achieved using existing, mature technology, or how emissions from a ship might be reduced to zero. This does not necessarily represent the approach used by prospective ship owners when specifying new tonnage.

In practice, the technical specification of a new ship is tailored to an owner's expectations of the market in which they intend to operate. Considerations include expected revenue, costs and the profitability of the specification. Constraints placed on the specific selection include the availability and performance of technology, availability of finance and the regulatory backdrop to the ship's operation.

The objective of this modelling work is to produce a simulation of the decision making process used in the specification of a newbuild ship or the retrofit of an existing ship, and combine this with a suite of ship design synthesis tools. This allows different input parameters to the decision process (e.g. regulation, fuel and carbon price or other market based instruments yet to be defined) to be varied to explore how they result in different predicted ship specifications.

This analysis is deployed in a system model. The system model is a time-domain simulation of the evolution of the global shipping fleet including investment in new ships, retrofit of existing ships, ship operation, trade flows, shipping logistics, shipping economics and shipping energy demand and emissions. The model represents fleets of different ship types which are broken down further into aggregations of ship size and age. It is the technical specification of the ship size and age categories of a given ship type at a given point in time, which is the focus of the work described in this paper.

### The general approach

Ship design has been presented as a paradigm of the design of complex products. The structure of the design models that result have been described using a complex interconnected network.

This complexity means that the level of automation in a ship design process must be carefully considered. Various types of parametric models that can be used in computer aided ship design have been identified, but both the utility and limitations of automated parametric models, specifically that they are only applicable to ships based on their fixed topology (although dimensional ratios may change), must also be considered.

This introduces a challenge in the Low Carbon Shipping project, of assessing the impact of approximately 70 carbon dioxide reducing technologies (CRTs) over five fuel choices and 10 design speeds, a total of 3,500 design points for each ship type (before different combinations of carbon dioxide reducing measures (CRMs) are considered). The solution is to produce a suite of modelling tools that operate at different levels of detail. The highly detailed models can be used to define modifications to the topology or scaling relationships in simpler parametric models, thus allowing the design space to be explored.

Most of the CRMs that are being investigated in the Low Carbon Shipping Project when taken in isolation have a relatively small effect on CO<sub>2</sub> emissions.

Several single CRMs have already been investigated and in some cases implemented in order to reduce fuel costs, especially those which have a short payback period or are quick to implement, such as slow-steaming, trim or voyage optimisation.

Within the system-wide context of the Low Carbon Shipping project, three key points arise when considering CRMs:

- Existing studies of CRM performances should be used where possible to allow a wide range of technologies to be included
- Combining CRMs needs to be considered; especially when individual technologies only lead to small savings and interference effects may exist
- The flexibility to change the operational speed and its resulting large effect, both on baseline emissions and the effectiveness of CRTs.

These considerations require that the CRMs be assessed both in combination and at a range of both design and operational speeds. The practice of adopting “packages” of CRTs, specified by marine engineers and naval architects, to be applied together to a ship design was not adopted. Instead, the overall shipping system model, including the engineering assessments of the performance of the technologies, will be used to determine which “packages” are desirable, taking into consideration the overall operational and economic environment.

This analysis, in some cases essentially a double check of published data, is required for two reasons. Firstly, equipment suppliers may quote best-case performance, or only have data for a limited range of ship types and sizes. Secondly, the wide scope of the shipping system model introduces the need for more detailed information in order to represent the CRT correctly. For example, technologies such as waste heat recovery may

not offer uniform savings over the complete operational speed range if they are optimised for the design speed.

### Detailed parametric ship model

The detailed parametric ship model is needed to correctly size CRTs to fit the ship and the ships have to be designed with enough accuracy and detail to ensure that the ships realistically reflect the overall impact on cargo capacity and cost. Thirty-six parametric ship design models were generated (specific to ship types, sizes and design speeds), based on common design assumptions and a common data set. This covers container ships, bulk carriers, oil tankers and LNG tankers. These four ship types are modelled in four size categories - corresponding to limits such as Panamax, and two or three design speeds (assumed to be at 75% MCR).

The detailed parametric ship model is used to investigate and characterise the ship impact of CRMs, particularly those of a technological nature, so that they can be applied to a wider range of ships in a simpler parametric model. The technical information needed to incorporate the CRMs into the ship design model is obtained from references and, importantly, the partner subject matter experts in the Low Carbon Shipping project.

Figure 1 illustrates one of the detailed parametric models produced in the Paramarine software. It is important to note that this model contains both a geometric model of the ship's arrangement and numerical sizing and performance data, so allowing the full impact of CRTs such as sail assistance and LNG fuel, which effect the

Figure 1: Detailed Parametric Ship Model, showing features such as main machinery and cargo support equipment

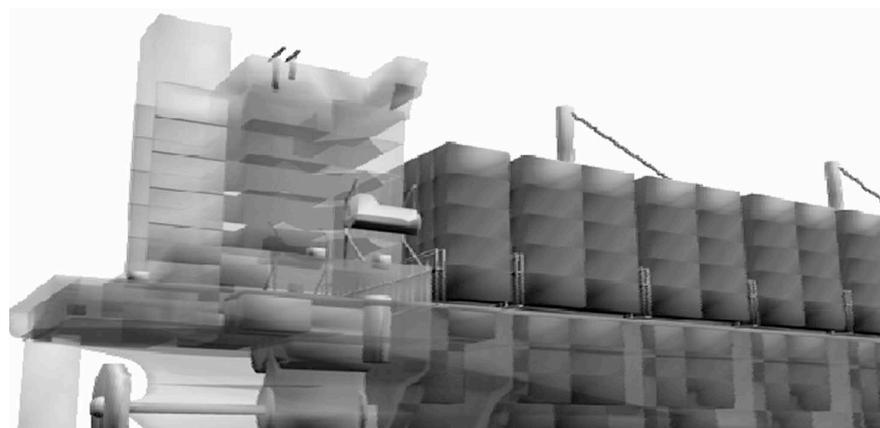


Figure 2: Ship Impact Model

overall general arrangement, to be assessed. Adopting LNG causes large changes to the ship that have to be considered carefully in the ship impact model.

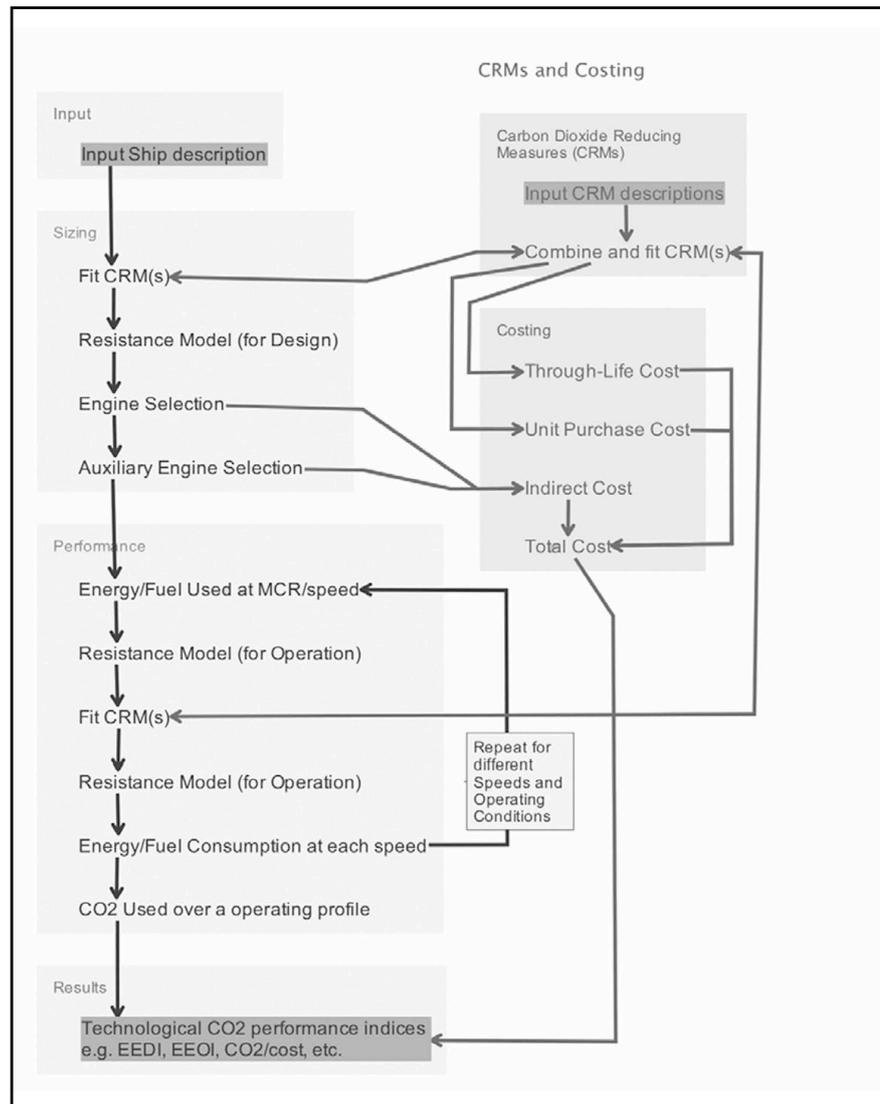
The detailed parametric ship design models were generated using a combination of UCL data, data from equipment suppliers' catalogues and ship design textbooks. Although the UCL data is detailed, it is derived from warships and some aspects, such as structural weight and distributed systems, were of uncertain applicability to cargo vessels. In some cases, weight estimates could be replaced with those known to be more suitable, but as a validation exercise, the resulting ships were checked by comparing information such as deadweight/displacement against detail given by Significant Ships and Clarksons, in order to check the assumptions such as installed power to power usage were correct.

### Ship impact model

It is thus necessary to make a number of assumptions in order to simplify the process of generating ship designs in order to investigate the effect of combinations of CRMs on the ship. This model applies the CRM impact data derived from the detailed ship model to a wider range of ships that can have design displacements and speeds different from the thirty-size example ships used.

Figure 2 shows a basic flow diagram of the ship impact model:

- The input ship is described by 52 parameters that can either be described by the user or the user can select from 1 of the 36 ships that have been created by the detailed parametric model. The user also selects which CRM or CRM combinations they want to examine.
- The model then sizes the ship and CRMs by initially providing information to the CRMs about the ship characteristics in order to correctly size the CRMs to fit the ship.
- The cargo impact can then be calculated from the sum of the cargo impact due to the technology and the cargo impact due to changes in the ship such as main engine size and auxiliary engine size (generally, changes in main and auxiliary engine



power have the bigger effect on emissions, rather than cargo weight impact). After this the resistance model is run at different speeds and different ship conditions, with the new characteristics of the CRM combination at the new speed being found before running the resistance model again. This is an iterative process but the iteration is ignored because the changes to the overall ship are generally small.

- An operating profile is then used that provides the time spent at each speed and in each condition in order to work out the average fuel consumption and CO<sub>2</sub> emissions.

On the first time through this process default values are used in order to work out the emissions of the baseline ship. The next time looks at the effect of the selected CRMs.

The main engine cannot be changed for retrofits and CRMs have a description as to whether they can be retrofitted or not.

This process assumes that any changes to the ship impact on deadweight, keeping the draft, displacement and hullform are unaffected. This means that a new draught from a new displacement does not have to be calculated each time the ship is modified by a CRT.

The CRMs, including fuel changes, are described in single files, external to the main executable, so that the ship impact model software does not need to be modified when a new technology is defined. The CRM files can include changes in stability, layout or any other additional changes if they are found to exist in the detailed ship model for specific CRTs. For example, to estimate the performance of solar power, the deck

area of the ship is required. The simplified ship impact model does not contain this information, but the assessment performed using the detailed parametric model allowed the derivation of a relationship between ship type, waterplane area coefficient and the resulting available deck area. Thus, the ship impact model can represent layout sensitive technologies without itself containing a model of the ship's layout.

The ship impact model allows combinations of CRMs to be assessed quickly. This allows "packages" of CRMs, and their resulting ship impact and combined performance, to be examined. Combinations of CRMs may have no interaction or may be incompatible. Incompatibilities are a function of the nature of the technology, e.g. pre-swirl vanes and contra-rotating propellers are inherently incompatible. For some CRMs the ship impact model can detect when two CRMs are attempting to alter the same ship characteristic in how the CRMs are described. For example two or more CRTs requesting a change in the auxiliary engine fuel (denoted by a change in carbon factor will not be allowed to be used together.

Similarly, compatible interactions can be modelled. For example, if a technology such as sails reduces the MCR required for a given speed, then the performance of other CRTs that are dependent on MCR (e.g. waste heat recover, propeller design) will be changed appropriately.

## Ship impact database

The Ship Impact Database (SID) provides the interface between the detailed descriptions of the ship impact and emissions reduction potential of CRTs and the overall shipping system model. The population of this database involves two main tasks:

- Simplification of the representation of the impact and emissions reduction of a CRT in a manner that retains the key characteristics but can be rapidly computed in the shipping system model.
- The presentation of the data to the shipping system model in a uniform, consistent and human comprehensible manner.

This second task is significant in that a simplified representation of the emissions reduction and ship impact of a CRT, derived from the parametric or ship impact model,

can thus be used in discussions with project partners and other stakeholders to elicit expert opinion on the results obtained.

The SID consists of an Excel spreadsheet, with titled columns of numerical and textual data, which can be read in by the Matlab based shipping system model. For each CRT, seven types of information are held in the database:

The emissions reduction potential of the CRT is given both as a maximum that could be achieved for the ship design; i.e. that achieved at the "optimum" operating point, and that achieved in service. This means that the maximum achievable saving with a given CRT could, for example, scale linearly with ship design speed, but can also be reduced by operational conditions above or below this design speed.

Emissions reduction potentials are described algorithmically. As the LCS project is ongoing, the exact choice of algorithms is constantly under review, but the latest database structure under development will allow reductions to be; constant, proportional or inversely proportional, maximum at a design point (i.e. quartic) or a step function. Currently they scale with; cargo deadweight, design speed and operational MCR. A slight complication is that different CRTs will reduce the emissions in different ways.

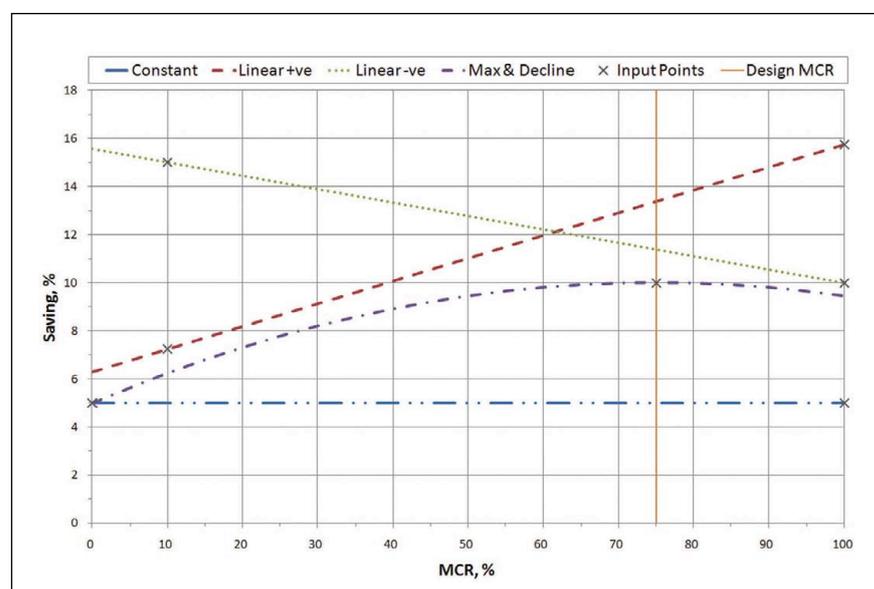
Practically, the algorithmic relationships are described by giving the coefficients and stating the type of relationship and input variable.

Figure 3 illustrates these relationships for a generic technology. It also shows another advantage of this method, in that potentially complex relationships may be captured with relatively little input data. For some CRTs, it will be possible to generate the curve based on two estimates (minimum and maximum) and an understanding of the underlying physics (e.g. proportionality to Froude number).

It is important to note that this simplified representation of the savings offered by a CRT is not attempting to be absolutely accurate at all points and for all ship design parameters. Instead, it is attempting to capture the broad characteristics of the technology, with the emissions reductions and ship impacts described to a level of accuracy commensurate with that of the overall shipping system model inputs.

As noted above, the ship impact of a CRT is expressed as a loss in cargo deadweight. This significantly reduces the effort required to assess the impacts of the large range of CRTs in the LCS project, and can be used to generate larger ships to carry the same cargo. The ship impact is described as coefficients in an algorithm, as per the emissions reduction potential. Currently most impacts are linear with size or propulsion power, but additional relationships are being added to represent efficiencies of scale found in some technologies. Ship impacts can be positive or negative.

Figure 3: Examples of saving relationships relative to operating MCR



A simple flag is used to represent the compatibility of a CRT with each of five fuel types (HFO, MDO, LSHFO, LNG and H2).

### Specific fuel consumption

Changes in the SFC caused by the addition of a technology can also be represented. These are with reference to baseline SFC values.

A list of incompatible technologies is provided for each CRT. This is of primarily of interest for the various hydrodynamic and flow control devices. A flag is also included to indicate when a technology is incompatible with NOx and SOx scrubbing technologies

A yes/no flag indicates whether a technology can be added in a retrofit. It is assumed that a refitted technology has the same savings and ship impacts as the technology fitted at build.

The availability of a technology (when it first becomes available and when it becomes a mass-market item) is represented in two ways. For some technologies that have a clear division into short, medium and long term concepts, multiple CRT entries are included. For all CRTs, a date is provided for the technology becoming available, and another for it becoming developed. This allows some degree of technology learning to be represented. Dates are broadly divided into five and 10 year increments for simplicity of estimation.

Some CRTs will not be applicable to one or more of the four ship types under consideration. More commonly, the savings and ship impacts will vary between ship types. These are represented using an indication of the applicability of the CRT. Where different relationships are needed for different ship types, the CRT can be repeated with different applicability statements.

The purpose of the shipping system model is to represent the whole shipping system, in order to understand how the components of the system (economics, logistics, technology, regulation, trade) interact with each other. This presents a challenge: to find the right balance between the levels of detail required to produce meaningful and realistic whole system analysis, whilst at the same time maintaining solubility.

In practice, this requires the representation of shipping CRMs in enough detail to explore their relative and combined technical and economic impacts, but with the minimum level of detail required in order to ensure

transparency, clarity and computational tractability. The CRMs are represented in less detail and fidelity than the ship parametric and impact models, but by regularly feeding back the outputs of system model ship specifications, any shortcomings in accuracy can be assessed and corrected as required.

The shipping system model can be used to explore the feasibility of a wide range of CRMs over the entire global fleet of ships (if so desired). The CRMs that are suited to a VLCC might be very different to those suited to a small container ship. This is due to the specificity of operation, economics and technology of different ships. For this reason, the system model divides the global fleet into ship types, and each ship type is divided into sub-categories of ship size and age.

Specific operational, economic and technical parameters are derived for each of these sub-categories and deployed to find their individual expected specification.

### Technical modelling

At each time-step of the system model's analysis, a technical specification for a newbuild ship in a given ship type/size category is derived, and the existing fleet of ships is evaluated for the viability of retrofit or operational change.

The shipping system's technical modelling provides the input to the economic modelling, which requires estimates for the calculation of annualised operational costs. The technical specification of the ship is also used in order to calculate the cost of a technology, as the costing information is held as an algorithm relating it to different ship parameters.

In the current version of the system model, a ship's technical specification is defined by 25 parameters including deadweight, installed main and auxiliary power, design speed, operating speed, length, beam, draught, main engine specific fuel consumption, scrubber and ballast water treatment specification etc.

Those 25 parameters are used to define the deviation between a baseline ship's characteristics, and those of a new design point. For example, the ship impact data describes the impact of a CRT (e.g. bulbous bow) on a given parameter (e.g. main engine installed power). The new design point associated with the implementation of that CRT has an adjusted installed main engine power and this is then used to calculate change in the overall design's energy

consumption. For the case of the main engine this can be thought of as a change in the ship's 'as designed' fuel consumption per day ( $TPD_d$ ).

The 'as designed' fuel consumption can be thought of as the fuel consumption that might be measured on a sea trial in ideal conditions. In real operations, it is rare to achieve the same performance, particularly as the ship ages and the hull fouls, engines wear etc. It is also the case that the ship may not be operated at the speed at which it was designed and this can have a significant effect on the fuel consumption. To allow for these considerations, the corrected fuel consumption  $TPD$  at a given state  $i$  (e.g. loading condition) is calculated according to equation 1,

$$(1) \quad TPD_i = TPD_d \cdot f\left(\frac{V_i}{V_d}\right) \cdot f(L_i) \cdot \frac{1}{\eta_p} \cdot \frac{1}{\eta_w}$$

where  $V$  is the operating speed (average over a voyage),  $V_d$  is the vessel's design speed,  $L$  is the ship's loading condition,  $\eta_p$  represents the deterioration due to wear, fouling etc and  $\eta_w$  represents a correction due to metocean effects (wind, waves etc). As calculations are performed on annualised figures for fuel consumption  $FC_{pa}$ , this is obtained using the corrected fuel consumption in each state and the time spent  $t$  (in days) in each state, as shown by equation (2).

The GHG emissions (and any other emissions) associated with this are calculated by multiplying the fuel consumed by its associated emissions factor.

$$(2) \quad FC_{pa} = \sum TPD_i \cdot t_i$$

Whilst these equations are only for the main engine fuel consumption, they are also performed for the auxiliary engine and a boiler (e.g. in the case of crude tankers). Calculations are performed for each fuel used so should the main engines consume heavy fuel oil and the auxiliaries marine diesel oil, this will be accounted for.

### Economic modelling

There are three main components of economic modelling, for the purposes of this paper only a high level overview is provided. They include:

- Operational cost estimation
- Capital costs estimation
- Investment evaluation.

The operational costs referred to here are the voyage costs. These include the fuel (and carbon if included) costs, the port dues and the canal charges. The fuel costs are calculated for each year as a function of the fuel consumption and the fuel price. Fuel price scenarios are an input to the shipping system model. If the CRT increases a ship's energy efficiency, relative to a baseline ship it will reduce the fuel consumption per annum and therefore the fuel costs. Additional to those operational costs are the annualised component of any through life cost (e.g. maintenance, consumables) of the CRT.

Capital costs in this instance are the capital costs of the CRT. They are estimated by scaling based on an indicative ship parameter e.g. the cost of waste heat recovery data is scaled according to the installed main engine power.

Other operational costs (crewing, maintenance, other consumables etc) are included implicitly based on historical datasets.

The justification for the inclusion of a CRT on a ship is that it will be economically rational. That is to say that due to cost savings (fuel savings or carbon reduction if there is carbon pricing), any costs incurred in fitting the CRT are justified. A standard accountancy tool for calculating this is NPV (net present value), as shown by equation (3).

$$(3) \text{ NPV} = C_0 - \sum_{t=0}^T \frac{(R-C)}{(1+d)^t}$$

Where  $C_0$  is the capital cost of the CRT,  $R$  is the revenue that the ship will generate (including any changes due to the presence of the CRT e.g. loss of dwt),  $C$  is the cost (e.g. including cost savings due to the CRT and the operating costs associated with the CRT),  $d$  is the discount rate (the interest rate or 'cost of money' for the ship owner) and  $T$  is the number of years over which the evaluation of NPV is applied.

A modified version of this equation is used in the shipping system model in order to consider the implications to a ship owner's profits as a result of the installation of an individual CRT or a suite of multiple CRTs. The CRM or suite of CRMs (because as well as CRTs, this evaluation also includes options such as switching fuels, changing speed or

implementing other operational measures such as weather routing) that maximises the ship owner's profits is then the solution that is used to specify the newbuild or existing ship (of a given type/size).

Feedback from the system modelling gives an indication of what combinations of CRMs are most probable in future scenarios. These combinations have been assessed on the basis of the simplified technical modelling described in Section 6.1. The purpose of the feedback is to validate these simplified calculations and to check that the performance and ship impact estimates are correct and to further assess their feasibility with detailed ship design models.

### Summary and future work

This paper has described the modelling techniques used in the ongoing project "Low Carbon Shipping – A Systems Approach". It has been noted that, in order to realistically assess the application of CRMs, a more complete socio-techno-economic analysis is required. This has implications for both the breadth of ship impact analyses that must be carried out, and also necessitates the development of a transport-system level model incorporating ship impact and abatement option performance.

The technical analysis uses separate models of high detail level to populate a simpler ship description that can be incorporated in the whole system model. This allows the complete range of influences on the adoption of a CRM to be considered, including basic technical feasibility, return on investment or profit, regulatory compliance and broad economic consequences.

The shipping system model allows a wide range of possible future scenarios to be investigated, incorporating CRMs with a range of economic factors. This allows the application of abatement options to be undertaken on an economic basis in response to the broader scenario.

The shipping industry may soon experience combinations of new regulations, uncertain fuel prices and the arrival of new and potentially disruptive technology. Understanding what broad trends (e.g. speed and fuel choice) and desirable CRM packages might be most suitable over the medium and long term is complicated, and requires more than a purely design oriented approach; it

also needs to bring in consideration of economics, logistics and regulation.

Given the difficulty in predicting the future, the shipping industry can benefit from tools to help it cope with the anticipated changes and to investigate which CRTs/CRMs are robust enough to be applied in different socio-economic scenarios.

A potential difficulty in examining the complete shipping system is that, by necessity, calculations must be performed using lower detail levels, leading to a loss of accuracy. Within this project, this is being addressed by the retention of high detail level models, to allow potentially desirable CRM combinations to be assessed. This parallel modelling approach should ensure that this work is credible both from the detail engineering, and overall system perspectives.

The Low Carbon Shipping project is moving into a new phase of analysis, with the incorporation of more detailed versions of the ship impact database into the shipping system model. This will allow the main campaign of simulations to be carried out over the following months. It is expected that this investigation will allow the identification of several CRMs and combinations of CRMs that, when subject to a socio-techno-economic analysis, are of interest for more detailed examination. This information will be fed back into the detailed parametric ship model to allow further investigation of these options. **NA**

### Authors biographies

John Calleya completed his MEng in Naval Architecture at University College London in 2010, which included a 14 month placement working as a submarine naval architect for BAE Systems at a shipyard in Cumbria, UK.

Rachel Pawling completed the MEng in Naval Architecture and Marine Engineering at University College London in 2001 and in 2007 completed a PhD thesis on the application of the Design Building Block approach to innovative ship design.

Tristan Smith is a lecturer in energy and transport at the UCL Energy Institute. He has an MEng in engineering and an MSc and PhD in naval architecture.

Dr Alistair Greig is a Chartered Marine Engineer and Senior Lecturer at UCL. Prior to UCL he was with UK MoD (RCNC).

## Calibrating the future, reprise

Tristan Smith explains the latest developments at the Low Carbon Shipping Project.

The operating consequences are slower speeds and a period of significant interest in 'eco designs'. To calculate overall trends in technology and emissions from shipping, modelling of technical choices in ship design needs to be coupled with analysis of the likely responses, behaviour and investment attitudes given a scenario for the regulatory regime and the macro-economy.

Take-up of energy efficient technology can come about in four ways: eco-advantage (a shipping company pushing the sustainability agenda beyond what appears to be the underlying cost-benefit, because they believe it will increase market share); command and control regulation to achieve a minimum standard (e.g. EEDI), cost-benefit (due to fuel price as a component of operating cost), cost-benefit (due to carbon price as a component of operating cost).

Many previous analyses (e.g. IMO 2nd GHG study) have used a policy tool known as a Marginal Abatement Cost Curve (or McKinsey Curve) to estimate likely take-up of technology. These curves calculate the cost-benefit and are powerful in their ability to represent detailed information simply, but limited in their ability to model behaviour in the shipping industry because: they cannot mix command and control regulation with cost-benefit; they are overly simplistic in their representation of ship speed which has impacts on both revenue and cost and is of crucial importance in discussion about shipping's energy efficiency; they are typically applied in order to seek solutions which minimise social costs rather than the more natural behaviour of an industry which is a number of firms behaving in order to maximise their profits; they are unable to adequately represent the full range of substitutional and combinatorial ship design solutions, the effect of multiple interacting technical and operational interventions; they are limited in their ability to represent market barriers such as the split-incentive.

For these reasons the Low Carbon Shipping project has developed its own modelling suite, GloTraM which can combine the various drivers for adoption of technology with market barriers, in order to represent selection of newbuild and retrofit specification for firms on the basis of profit maximisation decisions. With respect to the existing studies, this is revealing some discrepancies, but also some important observations of behaviour and risks of unintended consequences such as the motivation for operating more technically efficient ships at higher operating speeds and therefore possibly negating the emissions reduction benefits of such designs.

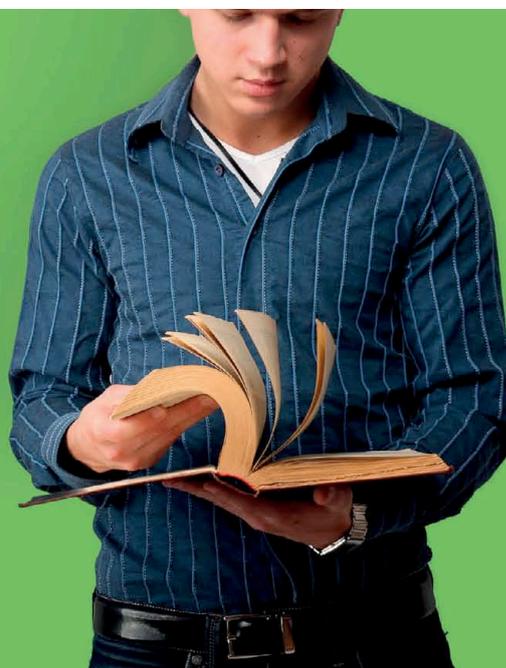
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# Adding efficiency to design

Conoship International has developed a new hull form consisting of the ConoDuctTail and the ConoSeaBow to improve the energy efficiency of Short Sea Ships. Guus van der Bles, Wieger Duursema and Jan Jaap Nieuwenhuis of Conoship International explain the latest innovations

**R**educing fuel oil costs is one of the main items in the Short Sea Vessel market, just as in most areas of shipping. Obviously the best way to reduce fuel oil costs is to improve the energy efficiency of a ship and consequently reduce its fuel consumption. As a result, numerous innovative bow forms emerged during recent years which claim to substantially improve the efficiency and reduce the fuel consumption. Examples are the Groot Cross Bow, and the Rolls-Royce Environsip bow, showing innovative hull shapes above the waterline. Until now Conoship International, a Dutch design office specialised in the design of Short Sea Vessels, was one of the few established design offices that did not yet develop their own “bow”.

At Conoship International however, we were convinced that the largest energy efficiency gains could be found in a vessel's aft ship. Therefore an extensive research programme was started to develop the most energy efficient aft ship design for short sea vessels. In the first instance the development focuses on small and medium sized general cargo vessels (between 1,500 – 10,000dwt). However, recent applications show that the developed aft ship form is also very suited for other type of vessels, such as short sea tankers.

Most of the small to medium sized general cargo vessels are ships with a relative high block coefficient (up to 0.88) and with speeds of between 10 and 14knots, resulting in Froude Numbers of about 0.20 to 0.25. For many of these designs, one or more of the main dimensions are restricted, due to restrictions at the operational area, such as width, length and draft restrictions because of locks, bridges, or water depths, while at the same time a high deadweight is required to be economically viable.

## Aft ship development

The research programme was started with an analysis and evaluation of frequently

applied aft ship forms for General Cargo Vessels. This analysis was (partly) made in co-operation with MARIN and Delft University of Technology. The analysis also included numerous discussions with various shipowners regarding the merits and disadvantages of various aft ship hull shapes. The analysis provided the following conclusions:

- For most general cargo vessels with little variation in their sailing profile, a single propeller installation, directly driven by a diesel (or dual fuel) Engine gives the highest efficiency;
- For many existing general cargo vessel designs the propeller diameter does not seem to be maximised, even though it is known for many decades that increasing the propeller diameter considerably improves the propulsive efficiency;
- three types of aft ship hull shapes could be distinguished:
  - Extreme pram type aft ships, see figure 1:
    - mostly applied for the faster general cargo vessels;
    - hull resistance at design draught is low compared to the other aft ship forms;
    - the hull efficiency is relatively low as well, due to the low wake fraction coefficient;
    - some bad experience in heavy seas, e.g. aft ship slamming and in shallow water;
    - power required for ballast operations in some cases considered to be relatively high, due to the short waterline length in ballast conditions;
  - Variations of a moderate pram type with a moderate stern bulb (e.g. Hogner), see figure 2:
    - resistance relatively low compared to traditional aft ship hull shapes;
    - better hull efficiency than pram-types due to a higher wake fraction coefficient;

- better behaviour in seaways compared to vessels with extreme pram type hulls;
- Aft ship shapes featuring a moderate tunnel (originated from inland waterway vessels with draught limitations):
  - tunnel shaped aft ships provide the possibility to use a slightly larger propeller diameter; however, for sea-going ships the tunnel shapes are not as extreme as for inland waterway vessels; for sea-going ships the top of the tunnel remains submerged, even in ballast conditions;
  - experienced captain owners are very enthusiastic about this hull type from a seakeeping point of view; the tunnel shape ensures a steady flow into the propeller even in heavy seas, reducing propeller racing, and providing sustained good thrust;
  - calm water resistance of the conventional tunnel shape is higher than that of aft ship shapes without a tunnel
  - nozzled propellers were infrequently applied, but received good critics from the owners that did apply nozzles, improve the efficiency up to speeds of 15knots.

See the following figures for example of frequently applied conventional aft ship forms.

According to Schnekluth (1998) V-type stern frames have the lowest resistance, U-shaped sections have a higher resistance and a stern with bulb forms can achieve the same resistance when fully optimised. Most recent aft ship hull forms are of the pram-type (moderate or extreme).

Extreme V-type sterns are not applied for small to medium sized general cargo vessels, mostly because the aft ship form is also influenced by parameters such as stability, required deck area, propeller inflow, required displacement, etc. Most hull form (resistance) optimisation studies that Conoship performed in cooperation with MARIN, generally seem to tend to pram-types.



Figure 1: Pram type

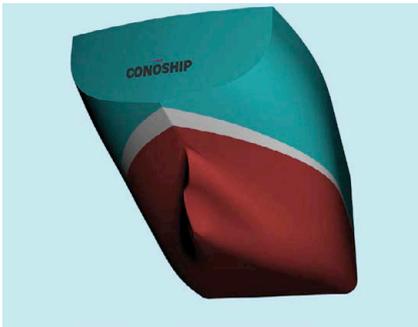


Figure 2: moderate pram with moderate stern bulb

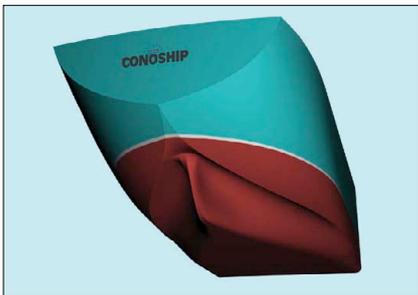


Figure 3: conventional tunnel shaped aft ships

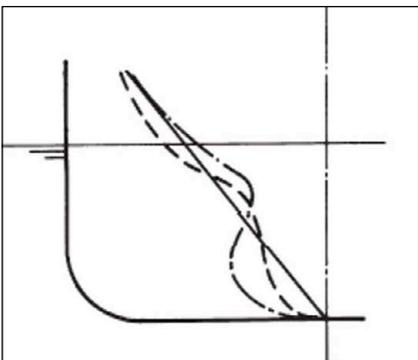
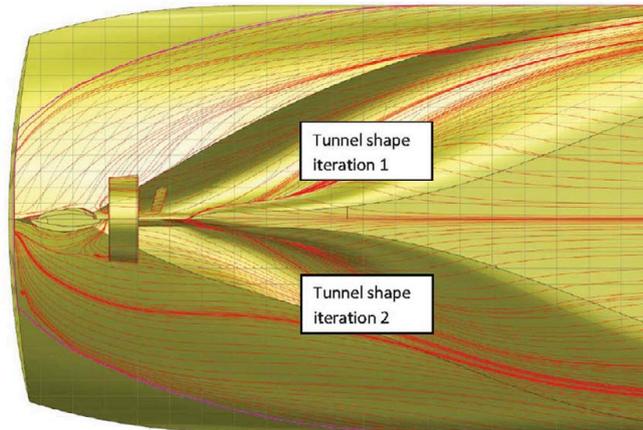


Figure 4: example of extreme U,V and bulb shaped stern sections (Schneekluth, 1998)

The results of the analysis of existing aft ship shapes led to the conclusion that the true challenge in aft ship development is to develop an aft ship with resistance characteristics of a moderate pram type,

Figure 5: various iterations of the tunnel shape in CFD



featuring an integrated nozzle and a tunnel shape in order to maximise the propeller diameter and the propulsive efficiency and to ensure good characteristics in adverse weather. This challenge resulted in the development of the ConoDuctTail.

### Development of ConoDuctTail

With the use of extensive CFD calculations, performed in close co-operation with hydrodynamic specialists SasTech and Van Oossanen, an aft ship hull-form was developed which incorporates the above mentioned features. Numerous CFD iterations revealed that to develop a successful ConoDuctTail hull form, with optimal combination of low resistance and best propulsive efficiency, the focus points are:

- Optimisation of the length and angle of the tunnel edges;
- Optimisation the integration of the nozzle and the hull;
- Optimisation of propeller design to resulting wakefield (as determined for full scale by CFD);

The resulting hull shape features a very “soft” tunnel with a reduced volume, compared to the conventional tunnel shapes.

With optimised tunnel edges and tunnel volumes, it became possible to develop an aft ship form with 17% less resistance than a conventional tunnel aft ship hull shape. The resulting resistance is comparable to the resistance of the moderate pram type. Even though the tunnel volume is reduced, the tunnel shape does still provide the possibility to incorporate a nozzle and a larger propeller diameter (up to 25% larger), because the propeller-tip-clearance could be reduced in

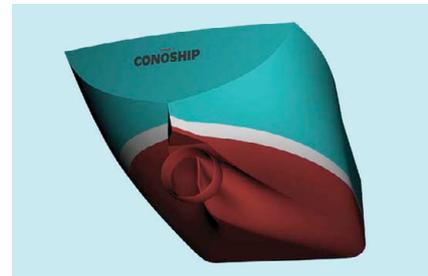


Figure 6: ConoDuctTail aft ship

this form. This results in quite an increase in propulsive efficiency compared to vessels without the ConoDuctTail, and in a considerable reduction of fuel consumption. As with most moderate pram types, the hull efficiency remains high and the wake field is even more uniform because of the tunnel. The overall result gives a very high efficiency and a resistance comparable to the resistance of a conventional general cargo vessel aft ship, consequently the combination results in considerably lower required propulsion powers.

### Practical application of ConoDuctTail

Unfortunately from a marketing point of view, the ConoDuctTail is positioned below the waterline and therefore out of sight and often unnoticed. The performance of the first practical application of the ConoDuctTail, a series of 3700dwt Sea/River vessels for WijnneBarends, see figure 7, is however very noticeable. While the main dimensions of these vessels are comparable to the main dimensions of other Sea/River liners, and therefore the block coefficient and Froude number as well, the installed power is about 20% lower. On their design draft of 4.30m,

these vessels carry 3,000dwt and reach a trial speed of 10.8knots at 748kW MCR. In practice they reach an average service speed of about 10knots, less than 3,0tonnes fuel per day, carrying 3,000 to 30tonnes of cargo; consumption figures of around 2.7tonnes per day have been reported for roundtrips, by careful consideration of the actual required speed/power for each part of the trip.

Further, no surplus power to cope with adverse weather conditions was required, because also in heavy seaways the continuous thrust delivered by the ducted propeller in the nozzle remains very high. With each ConoDuctTail design the performance of the vessel in adverse weather conditions is thoroughly checked during the design stage. As the application of the ConoDuctTail provides the possibility to operate vessels with a relatively high block coefficient with low propulsion power, it needs to be ensured that minimum power requirements are met, to maintain a safe speed in heavy seaways considering the relevant wave and wind condition in the foreseen operational area.

The developed ConoDuctTail consists of a unique integration of standard elements such as the tunnel shape, integrated nozzle and the propeller design. However, for each specific design the details of the tunnel and the nozzle-hull integration need to be optimised with the use of CFD calculations.

### Development of ConoSeaBow

Feeling confident that the maximum gains were reached in the aft ship, hull form developments at Conoship International now focus on the improvement of the bow form, i.e. the ConoSeaBow. As many others,

the elements considered for an optimal bow form are:

- The standard for calm water performance is set by an optimised bulbous bow. The calm water performance of a new bow form should come close to this standard.
- A new bow form should result in a reduced added resistance in seaway (during heavy weather conditions);

The development of the ConoSeaBow started last year at Conoship and the first results are applied on designs which are currently on the drawing board.

The ConoSeaBow features very straight and extended waterlines with small entrance angles around and above the design waterline, in order to reduce the added resistance in seaways. Instead of a bulbous bow that extends forward of the forward-perpendicular, a kind of an “inverse bulb” is applied, in order to develop a favourable interference between bow wave and shoulder wave. Optimal shape of the ConoSeaBow is strongly influenced by the design speed in calm water. Once again numerous CFD-calculations are required for the development and optimisation of the bow form. For each new design a CFD-optimisation for various draught/speed combinations is required to determine the optimal characteristics of the submerged part of the ConoSeaBow

### Modular hull form

The ConoDuctTail and ConoSeaBow can be used in combination with each other. However, it also remains possible to combine the ConoDuctTail with a bow



Fig.8: ConoSeaBow

form with an optimised bulbous bow. For example when there is little variation in sailing profile and a strong focus interest in calm water performance, combining the ConoDuctTail with an optimised bulbous bow provides the best results.

### Conclusions and further work

The ConoDuctTail and the ConoSeaBow provide an energy efficient solution for Short Sea Vessels: the EECS: EnergyEfficientConoShipform. Creating EECS energy efficient hull forms is considered by us as the best way to realise “Econology”: combined improvement of economy en ecology of our ship-designs! Reduction of fuel consumption and CO<sub>2</sub> emissions provides environmentally friendly and economical ships, amongst others expressed by their excellent EEDI (= Energy Efficient Design Index) values.

Initially developed for general cargo vessels, the ConoDuctTail is now also applied for other relatively full cargo vessels, such as Short Sea Tankers. Further work to improve the econology of Conoship designed short sea vessels is focused on emission-reduction of the propulsion installation using LNG for propulsion fuel. Emissions of CO<sub>2</sub>, Sulphur, NOx and soot particles can be reduced considerably by application of LNG, but the challenge is to create an economically feasible ship design, integrating the LNG-installation and LNG-tank in the most (cost-) efficient way. *NA*

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- Schneekluth, H., Betram, V., *Ship design for efficiency and economy*, Butterworth & Heineman, 1998  
 Klass Visser, naval architect, Conoship



Figure 7: Lady Anna

# Evaluating fuel saving devices

Rising fuel costs have seen fuel efficiency become a key driver for shipping and for existing ships there is a bewildering array of modifications. Dr. Claus D. Simonsen, senior specialist and team leader, numerical team and Dr Anton Minchev, chief naval architect, propulsion, of FORCE Technology discuss how to evaluate add-ons

One possible way for shipowners to save fuel is to equip ships with fuel saving devices, in terms of rudder, propeller and flow guide designs that are more efficient than conventional rudder-propeller configurations.

New devices can either be retro-fitted to existing ships or applied on newbuildings. In both cases it is interesting to rank their performance and know how much the device can save in order judge the return on investment (ROI) or payback time for the new device. Therefore, it is important to be able to quantify the performance of the conventional and new devices on the ship of interest.

Today, the best tools available for this are towing tank tests and calculation tools such as computational fluid dynamics (CFD). In this article we will discuss the possibilities provided by CFD for evaluation of fuel saving devices such as rudder-propeller configuration and fins.

## Towing tank versus CFD

The most commonly used method for checking hull-propeller configurations is the self-propulsion test conducted in a towing tank. However, model testing is costly with several rudder-propeller configurations, particularly for retrofitting where the hull model typically is not available. CFD is a relatively new approach for studying this type of applications, but it has shown to be a powerful tool for evaluating related marine applications. Therefore, it is natural to investigate the capabilities of CFD on fuel saving devices. By using CFD for evaluation of different rudder-propeller geometries behind the same hull, these costs can be diminished as CFD is a more flexible tool for this exercise.

In a number of projects performed through the Danish Centre for Maritime Technology (DCMT), FORCE Technology has investigated how accurate CFD can predict the performance of the individual devices compared to model testing, i.e. predict, for instance, propeller thrust, torque and power. Further, the projects focused on investigating potential power savings of the different devices.

By conducting these projects we found that 1) With CFD it is possible to evaluate and rank different fuel saving devices and give an indication of the power saving related to the fuel saving devices. This is in fair agreement with the results made in our towing tank tests.

2) CFD is an efficient tool for determining the flow physics in the stern region and for understanding the principles of the fuel saving device in question. This insight can be used to optimise the design of the device.

In the following we will present the relevant studies made in connection to the above findings.

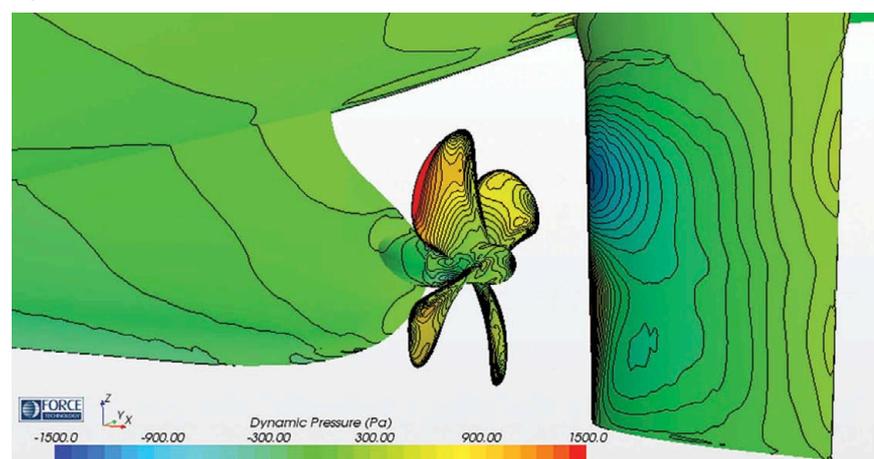
## Approach and method

In the work with CFD based predictions of the performance of fuel saving devices, different rudder types, rudder-propeller distances, rudder-propeller configurations and pre-swirl stator fins were evaluated behind a 180m bulk carrier in order to study how the different configurations influence the propulsive performance for a given speed at the ship's self-propulsion point.

The CFD simulations were conducted with the Reynolds Averaged Navier-Stokes (RANS) solver STAR-CCM+, which is the solver FORCE Technology applies for its numerical services. Simulations of the self-propelled ship are challenging from the point of view of handling the complex geometry and the large numerical model, which requires high performance parallel computing.

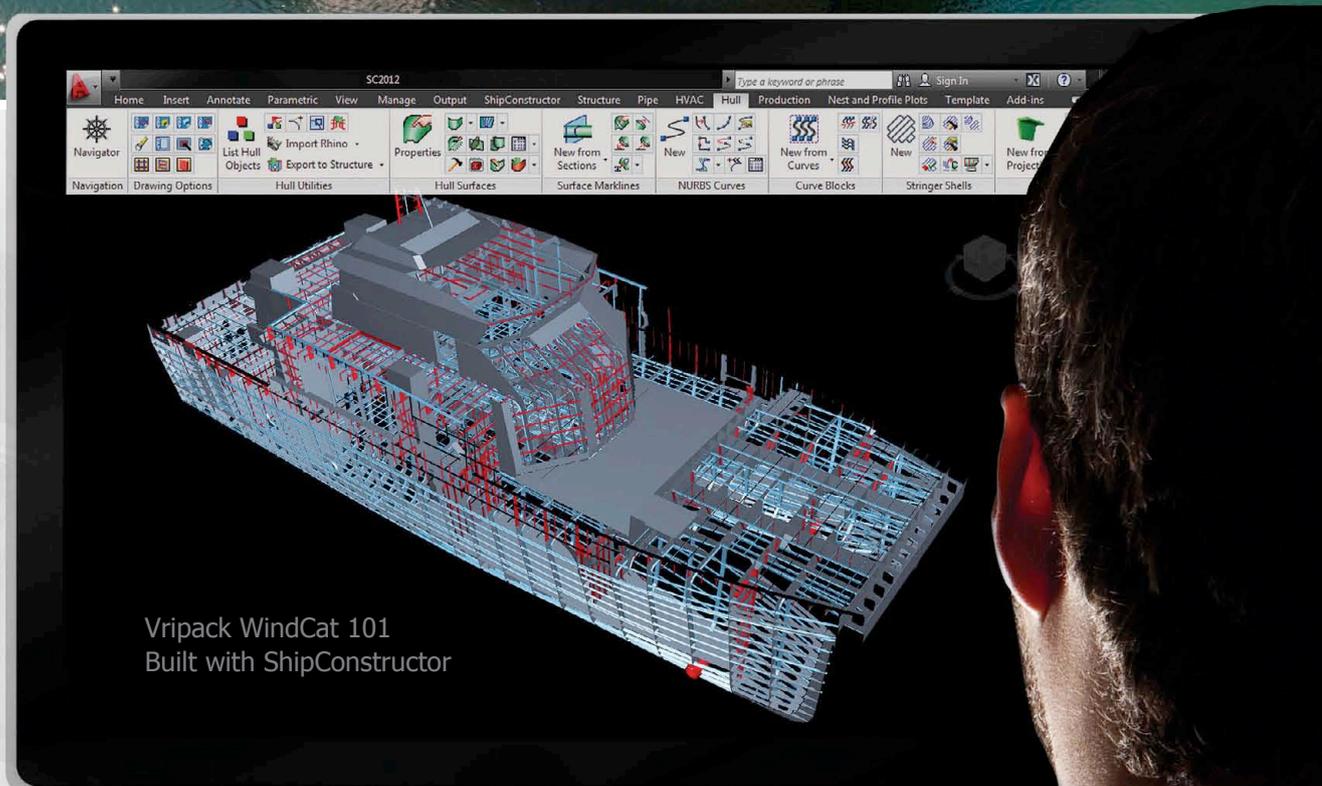
In the present work, both hull and rudder are modelled with a trimmed mesh, which is a hexa-dominant polyhedral mesh. The propeller is modelled with pure polyhedral cells. This type of mesh is assumed to give a better resolution of the geometry due to

Figure 1: Port side, pressure side. NACA rudder



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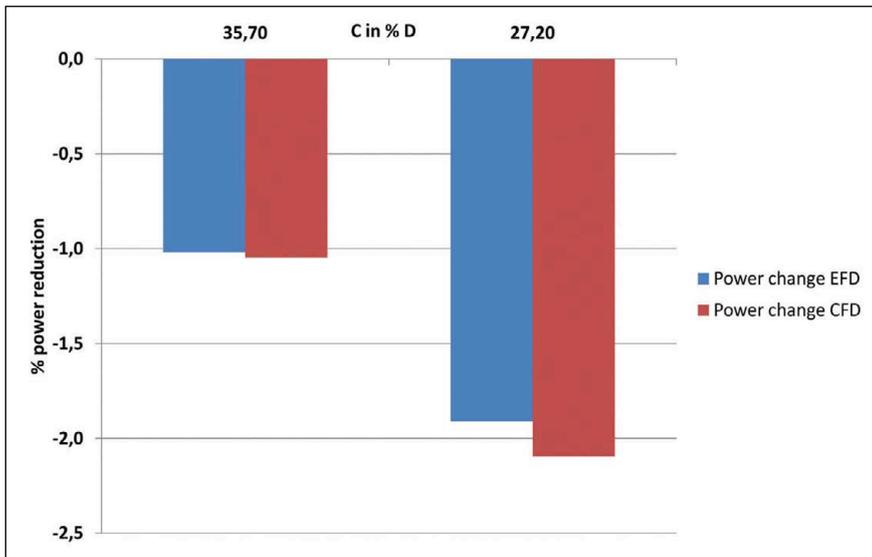


Figure 2: Computed and measured power reduction for NACA rudder in % base position value

the shape of the cells, particularly in the blade edge regions. Further, refinement zones are applied along the edges in order to resolve the steep gradients in these areas. In order to combine the hull and propeller meshes, a cylindrical region with the propeller is embedded in the hull mesh and the two are connected via an interface which is updated as the propeller rotates.

### Rudder influence on power

One way to influence the propulsive power for a given ship is to change the distance between the leading edge of the rudder and the propeller. A study, where a given rudder geometry was located within different distances from the propeller, has shown that saving in propulsive power of 1 to 2.0% could be achieved. The study, which covered self-propulsion conditions with three different rudder positions, was conducted with both CFD and towing tank (EFD). The goal was to quantify the saving and to check how accurate the power saving could be predicted by CFD compared to measurements.

Figure 1 shows the pressure distribution on the hull, rudder and propeller during the simulation and illustrates how CFD gives an insight into the flow. Figure 2 shows the saving in propulsive power for different positions relative to rudder base position with the largest distance for a given rudder geometry. It is seen that the

sawing is predicted quite well with CFD, compared to measurement indicating the potential for using CFD for this type of investigation.

Another example of the application of CFD for evaluation of fuel saving devices covers situations, where one rudder-propeller configuration is replaced with another. For instance in cases where a conventional configuration like the one shown in Figure 1 is replaced with a PROMAS solution, where rudder and propeller are more integrated as illustrated in Figure 3. A comparison

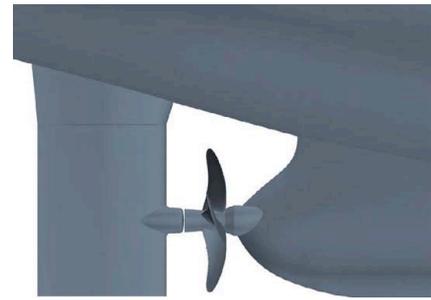
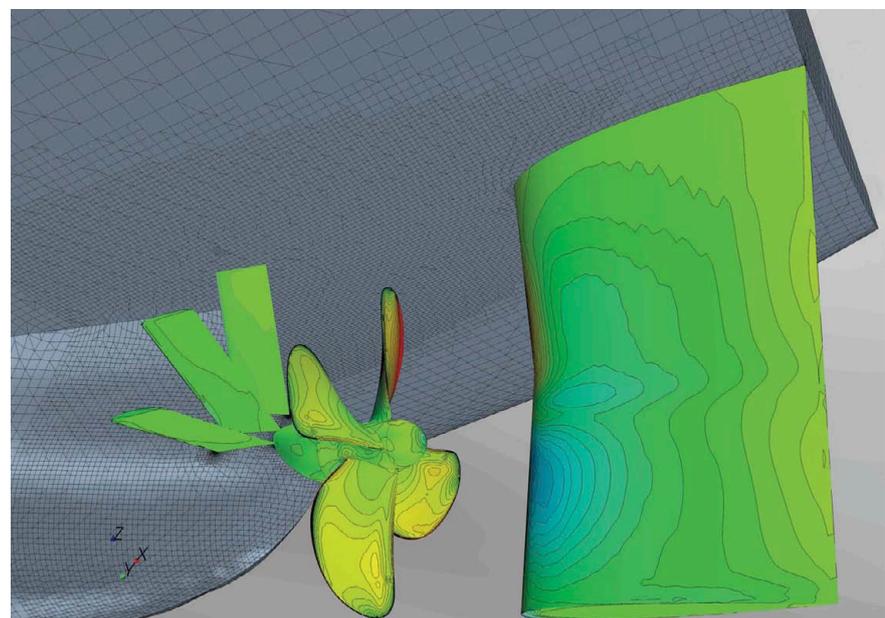


Figure 3: PROMAS design

of the change in performance between the two configurations was shown to give a reduction of approximately 3% based on the measured data, while the CFD simulation said around 5%. So in this case CFD was able to rank the two configurations by showing a performance improvement, but the actual saving was over predicted.

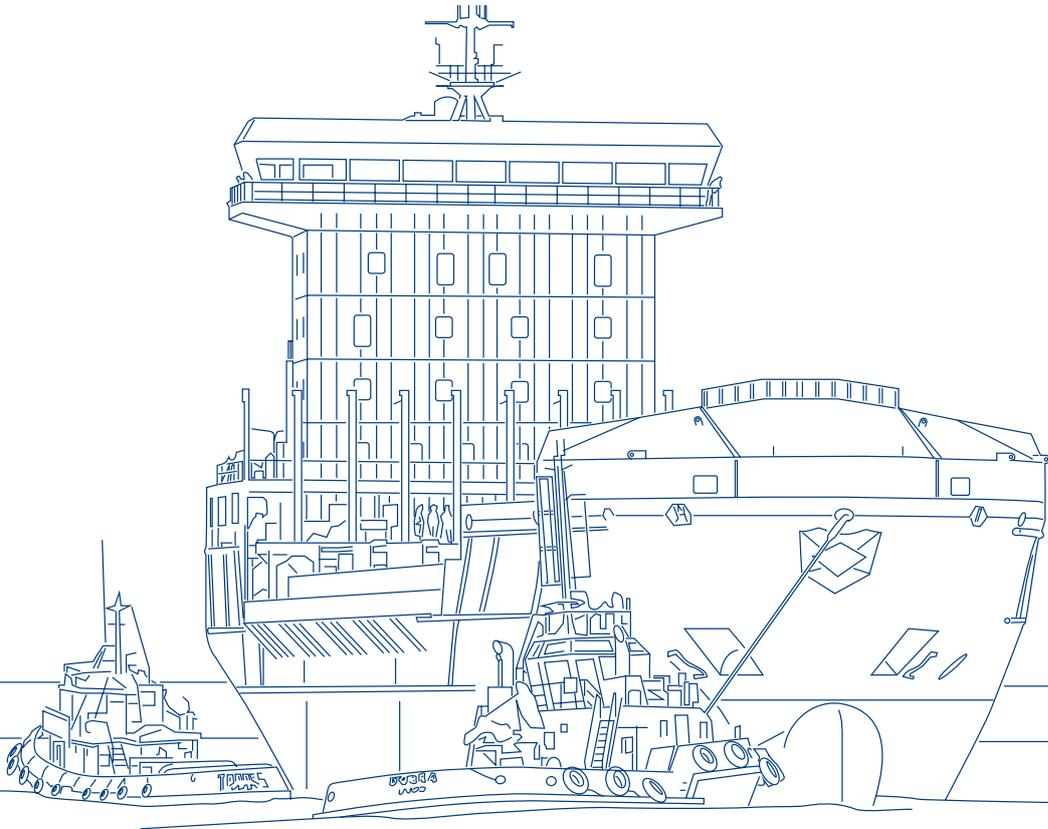
The final example of evaluation of a fuel saving device covered application of pre-swirl stator fins, which are fins located on the propeller boss in front of the propeller in order to improve the propeller inflow, see Figure 4. The application of CFD showed that in this case a potential saving of 1.8% could be achieved. The effect of the stator fins is strongly dependent on the orientation of the fins, and in this case, CFD was also used to “tune” the fin orientation to obtain maximum savings. *NA*

Figure 4: CFD simulation of pre-swirl fins





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# View from the bridge

Stéphane Neuvéglise, senior product business manager, AVEVA, explains how emerging technology will increase business agility and productivity in shipbuilding

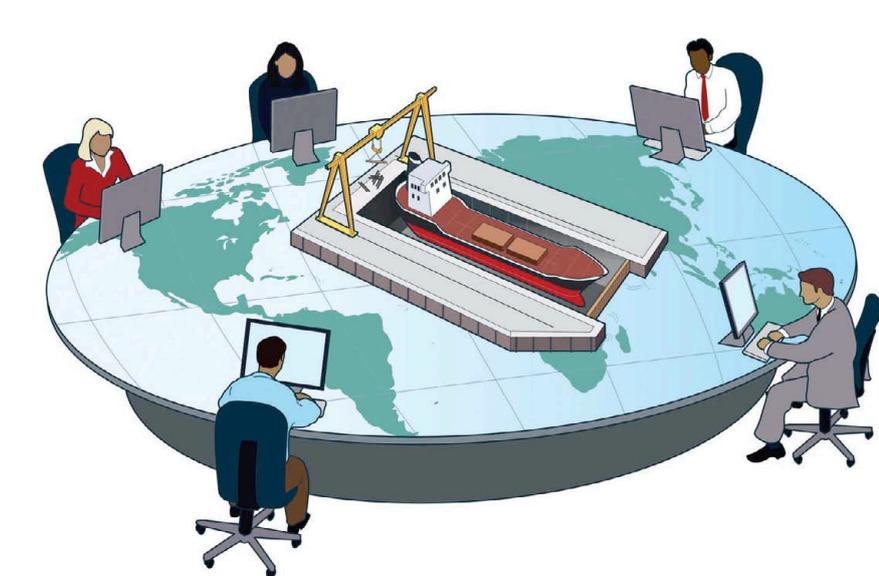
The development of increasingly powerful software for ship design and construction has enabled shipbuilders to meet the demands for more complex and sophisticated vessels. But, in certain respects, shipbuilding software has reached a plateau of functionality while the trend for bigger, quicker, cheaper and more advanced vessels continues its relentless increase. Compound this with a need for greater business agility in an uncertain global market in which input costs and output prices can fluctuate wildly and it is clear that shipbuilding is ready for a new generation of technology to meet new challenges.

The emphasis in all the capital engineering industries is shifting from specific task productivity – important though that continues to be – towards integrating business tools and processes to increase efficiency, capability and agility. Technology already provides solutions to this changing emphasis, but it is now about to undergo another revolution which stands to fundamentally change the way it enables and supports business processes.

## Current challenges

To say that technology has reached a plateau is not to imply stagnation – far from it – but there is a limit to how productive one can make an individual design task. The solution is to increase productivity at project level, as well as task level, but one of the biggest barriers to doing so has been the incompatibilities of the various software applications used. This not only makes it hard for the different engineering and design disciplines to collaborate, it also obstructs the necessary ability to control changes and keep all aspects of a design synchronised as it evolves. However, by integrating the engineering and design tools, and the information that they create and use, a higher level of overall productivity is now achievable.

Today, this integration is extensive in the most advanced marine solutions. Engineering and design data may now



The most advanced solutions adopt a more robust approach to maintaining only a single, definitive project model, managing access to it and transmitting only the incremental changes by each participant

be created directly in a common project model, where it can be controlled by the responsible discipline but, made available to all other disciplines that use it. An outfitting designer can see the work both of the hull designer and of the systems engineer as they change. Importantly, the many changes that occur do not have to impose straitjackets on other designers; they can be advisory, not prescriptive, so that each designer can see what needs to be changed, and why, but can either accommodate the changes at an appropriate time or challenge them if it is apparent that they create a problem.

As projects become bigger and more complex they demand more resources and hence greater ability to collaborate with project partners, suppliers and sub-contractors. FPSO and FLNG projects, involving global consortia of specialist businesses, clearly illustrate this, but even small projects can involve collaborative working. The integration described above must, therefore, be extendable across multiple sites anywhere in the world. Often,

this is tackled by duplicating the entire project database to every location, with the inevitable difficulties in keeping them synchronised. However, the most advanced solutions adopt a more robust approach of maintaining only a single, definitive project model, managing access to it and transmitting only the incremental changes made by each participant. This is achievable even where, for example, one location is designing a hull block and another the outfitting items that go into it.

But, there are still some fundamental limitations with the technologies used in all the capital engineering industries and here is where we are about to see the next technological revolution. It is being driven by a confluence of changes; in technology; in the ways we expect to use it and in the need to achieve a step increase in business performance.

## Changing landscape

Demographically, we are seeing a steady erosion of established skills and

experience and the arrival of a new generation of young professionals who not only lack the experience of their senior colleagues, but who also have quite different expectations of technology. For one thing, they are less prepared to put up with quirky user interfaces and excessive system administration; they expect the technology to just work and let them get on with the job in hand. And business itself has the same needs. Just as clunky, command-line driven software gave way to more productive and intuitive graphical user interfaces, so the next generation of technology is moving away from the keyboard and mouse paradigm and adopting the principles used in tablet devices. Users will feel as though they are interacting directly with the 3D model itself. Mobile devices will also become part of the project network and information will be made available to decision makers in tiered, configured

formats to enable them to make informed decisions and authorisations directly in the project model, wherever they happen to be. Reviews and approvals will diminish in importance as critical-path activities.

At the same time, competitive pressures demand that users be able to respond rapidly to business opportunities. Reducing project start-up time from days to hours and enabling more extensive re-use of previous design work will speed up project delivery, reduce costs and increase right first time quality.

Tackling the experience gap has been under way for some years now, as technology has enabled rules and best practice to be built into the design software itself. However, there are right and wrong ways to achieve this. The wrong way is to make such rules prescriptive, constraining the designer at every stage, but not explaining the reasons for the constraints.

The most productive solutions interactively check design against rules and standards (such as manufacturability) and apply changes in an advisory manner. This enables much more flexible working as the design is progressively and collaboratively refined from initial concept to a fully detailed and compliant definition. It keeps the designer in control and, equally valuable, less experienced designers can see why a particular feature is non-compliant and learn from resolving the issue. Technology is progressively extending this flexible way of working to bring more types of project information within its scope.

### Towards Lean Construction

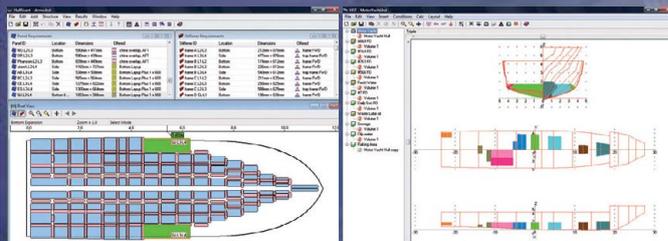
One-off, project-based manufacturing such as shipbuilding requires a fundamentally different methodology to volume manufacturing. Where the latter uses Lean Manufacturing principles, shipbuilding



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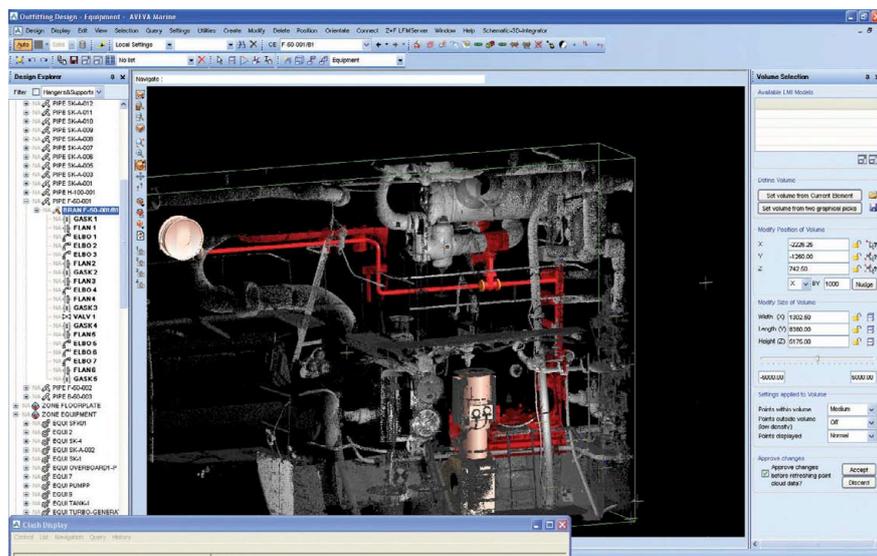


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Laser surveying is a powerful tool for creating accurate and detailed as-built 3D models of parts, sub-assemblies, hull blocks or even entire vessels

re-optimize the project plan in the light of changing specifications, unforeseen delays, resource clashes and so on. Critical decisions must be made quickly. Here is where the next generation of technology will add value in marshalling the necessary reliable decision-support information, direct from the project model, presenting it in an immediately usable form, and enabling approvals and authorisations to be made electronically within the project model itself, wherever the decision maker happens to be.

needs its own lean philosophy. This has long been aspired to, but until now, has lacked the catalyst to achieve it.

The prerequisite of Lean shipbuilding is tight, closed-loop control between design, production and construction in a manner which facilitates effective decision making and early corrective actions. Integrated shipbuilding technologies for engineering, design and resource management already enables much of this, but the long-awaited catalyst has now been created by the maturing of 3D laser surveying technology.

Laser surveying is a powerful tool for creating accurate and detailed as-built 3D models of parts, sub-assemblies, hull blocks or even entire vessels. It is inexpensive, quick and non-disruptive and can be performed almost anywhere. An obvious application is in quality control; it can be used by suppliers and subcontractors to verify dimensional accuracy of items before despatch to the assembly yard. The survey process creates a 'point cloud' of 3D coordinates which can quickly be compared with the design model. This provides an essential capability for Lean Construction: the ability to take prompt, informed action about non-compliant production. While the production of grossly inaccurate sub-assemblies is relatively rare, there are invariably degrees of inaccuracy and discovering these only during block assembly can be costly. By early comparison of as-built with as-designed,

it is possible to take appropriate mitigating action to protect the project schedule. For example, a dimensional error in a sub-assembly might be accommodated by making corresponding adjustments to adjacent parts still in the design (or even parts production) stage, rather than by costly rework.

Where projects involve a globally distributed network of production sites, it is particularly important to ensure that a hull module is fit for purpose before being despatched halfway around the world. Laser surveying is the ideal tool for this; the module can be quickly scanned and the point cloud data transmitted to the design team for review. The process can – and should – be used at every stage from parts fabrication to final assembly so that successive stages achieve 'right first time' construction. The Lean philosophy not only reduces costs, it makes an organisation more agile and, by rigorously eliminating waste of every type it also maximises quality of the finished product; Lean Construction can achieve the same result.

### Keeping the fleet afloat

In the commercial sector, Lean integrated shipbuilding will be driven by competitive pressures to deliver new vessels as quickly and cheaply as possible. However, in the naval sector different considerations apply. A naval shipbuilding project is high-risk, with many uncertainties of varying severity persisting well into the programme. Agility here is essential to continually

Further, the 3D laser surveys can be aggregated as construction proceeds to create an accurate and detailed model of the entire as-operating vessel. And if there is some uncertainty about parts of this model, local re-scanning can be performed readily, often even at sea. Such a model is an invaluable asset for planning and preparing for major refits to minimise the time spent out of service. Historically, the as-built condition could not be determined until the vessel was in dry dock, wasting considerable availability before the project could even begin. Now the preparation can proceed confidently, well in advance and the refit can be completed more quickly.

### Gaining an advantage

Shipbuilding is a conservative industry and shipbuilders adopt new technologies only when there is a clear return on their investment. By enabling new business processes as well as increasing task efficiencies, these new technologies offer a compelling value proposition in increased business agility, competitive advantage and productivity. Early adopters who grasp the opportunity to pioneer integrated shipbuilding methods may gain a disproportionate advantage.

In summary, while there are considerable business performance gains to be made even with current off the shelf technology, the next few years will see dramatic new ways of working in shipbuilding and across all the capital engineering industries. The Lean revolution is happening now. **NA**



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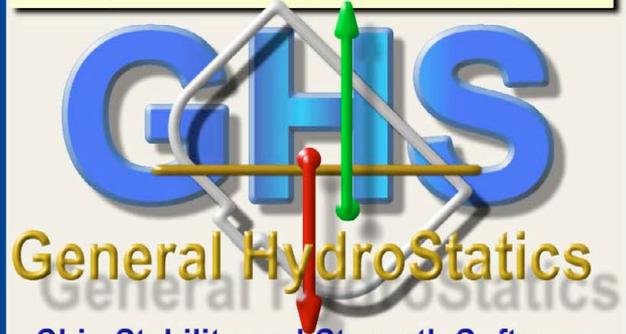
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# Dassault woos customers with new 'design experience'

Dassault Systems has renewed the marketing of its design package, V6 2013x 3DEXPERIENCE, and now offers users a design 'experience'. This step change in its approach to its software development allows the customer to lead the way, claims Dassault

**T**he predominant upgrade in Dassault Systemes latest software package is that it has changed its remit from a provider of software solutions to a supplier of 'experiences'. Whilst this may take some user's time to get their heads around, Dassault says that this change shows the way that the company is changing its approach to the development of its software.

"In the past we have developed products to produce tools for the industry and essentially we were pushing tools to the market. Now we have changed our way as we understand that it is better to study our customer's needs and challenges and to develop experiences [solutions] for this", explains Alain Houard, vice president, marine & offshore industry, Dassault Systemes.

These 'experiences' will be developed by the industry leaders at Dassault Systemes based on the experience that is needed by its customers. The company believes that by taking this route of, in essence, repackaging its solutions it will improve its market penetration.

At its users' meeting in Brussels in November Dassault customers explained how they would use the latest V6 platform, where the new 'experiences' have been brought in. Customers were still readjusting their thought processes and matching the terminology to the fit the new Dassault script. Dassault also claimed that the V6 platform will give users better output and has been easier to use than previous releases.

"Users will not need a lot of time to adjust. The user interface of V6 is still the same, what we have done is simplified the products", explains Houard.

The latest launch of Dassaults V6 2013x 3DEXPERIENCE platform



Alain Houard, vice president, marine & offshore industry, Dassault Systemes believe that the change in approach will boost the effectiveness of the software

will also bring more to its users with enhancements to its ENOVIA software for online collaboration. The V6R2013x update will enable CATIA V6 mobile users to design anywhere and anytime, even when the network is unavailable, while protecting IP and maintaining data integrity with the rest of the design team. ENOVIA VPM On-The-Go enables users to save data locally from a central repository, perform modifications and/or reviews when travelling and reconnect online to propagate local modifications to the central repository.

Allowing users to log on and change designs anywhere in the world also raises the question of security and how safe working like this can be. Houard ensures that: "Enovia V6 is secure for products. Banks use this software as well. The software can be set up so that it has its own data bank." He continues "Some countries are ready to come online to the cloud, where as some are not."

Houard highlights the example of a Chinese yard that Dassault Systems

is currently working with that are operating the V5 software. "At the moment the Chinese yards are trying to automate their processes and are at a more basic end of the software evolution, compared to other countries." Some of the more technologically savvy yards are currently looking for software at the front end that can be integrated and allow more collaboration, which will save both time and costs. Chinese yards are, however, still facing the next step up from technical drawings to a full CAD package.

Going forward Dassault Systemes aims to work closely with classification societies for the inclusion of the latest rules for damage stability and safe return to port, which they aim to have in their software package for 2014. "We are not reinventing the wheel, but we are aiming the development so that our customers can design in compliance", says Houard.

The 3DEXPERIENCE platform has been focused on the management of data, where new methodologies have been developed that allows customers to make more precise changes and work in a collaborated environment. The addition of the search tool net vibes within the software, also allows the user to search a database for parts and a gives a breakdown of these parts, which Dassault have claimed will speed up the users operation of the software.

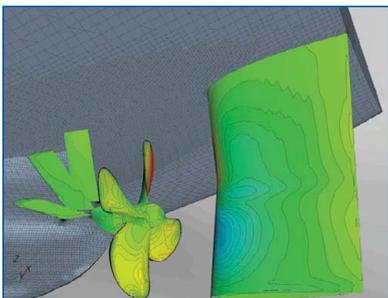
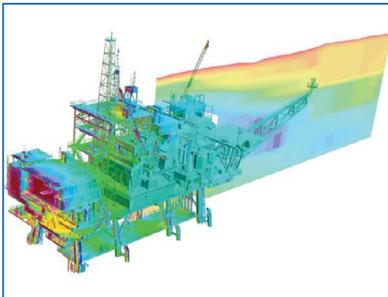
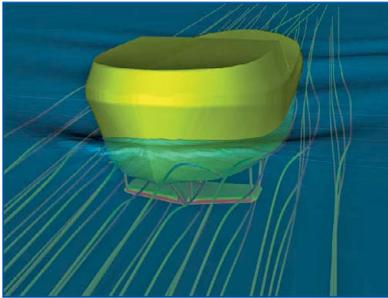
For marine users there is also a marine & offshore manufacturing planning application that will provide the foundation for all 3DEXPERIENCE shipbuilding manufacturing solutions and deliver a dedicated environment to perform manufacturing process planning, and large manufacturing assembly definitions. **NA**

# The Royal Institution of Naval Architects

## DEVELOPMENTS IN MARINE CFD

12-13 December 2013, Chennai, India

### CALL FOR PAPERS



Computational Fluid Dynamics (CFD) is now used to solve a wide range of maritime applications from resistance prediction to slamming loads calculation. While it may still lack the accuracy to match results obtained in real-life experiments, it can provide important insights into physical flow characteristics and offers an economic way to investigate a range of design options.

Generic CFD codes often lack some features and capabilities needed to address specific maritime applications. The presence of the free surface provides a major departure from conventional CFD applications. The need to represent this fluid interface accurately presents a considerable challenge, not least because its behaviour can vary considerably within the computational domain, and as a function of hull form and speed.

While it might not yet be possible to develop a single CFD tool suitable for all maritime applications significant progress has been made in the past two decades towards the development of the 'numerical towing tank' and 'virtual basin or cavitation tunnel'. Research and development work is still ongoing to enhance their stability, accuracy, computational speed and to integrate CFD into the overall design process.

This International conference will offer delegates an opportunity to meet and discuss the latest developments and practical marine application of CFD.

Papers will relate to the following topics:

- Practical applications of CFD techniques to marine design
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# FORAN links applications

Spanish-based Sener Ingeniera y Sistemas SA has developed its latest application for the complete management of its functional diagrams of onboard systems

The latest module from Sener the FORAN System Diagrams (FSYSD) has been incorporated in to the launch of Foran's latest software release V70R2.0 that came on to the market at the end of November.

The module aims to bring the user a more streamlined interface in production diagrams. For this Sener has replaced three existing modules with this one application. The modules that are replaced are SYVIEW (2D Diagrams), PIGRAM (pipe & instrumentation diagrams) and EPOWER (single wire electric diagrams).

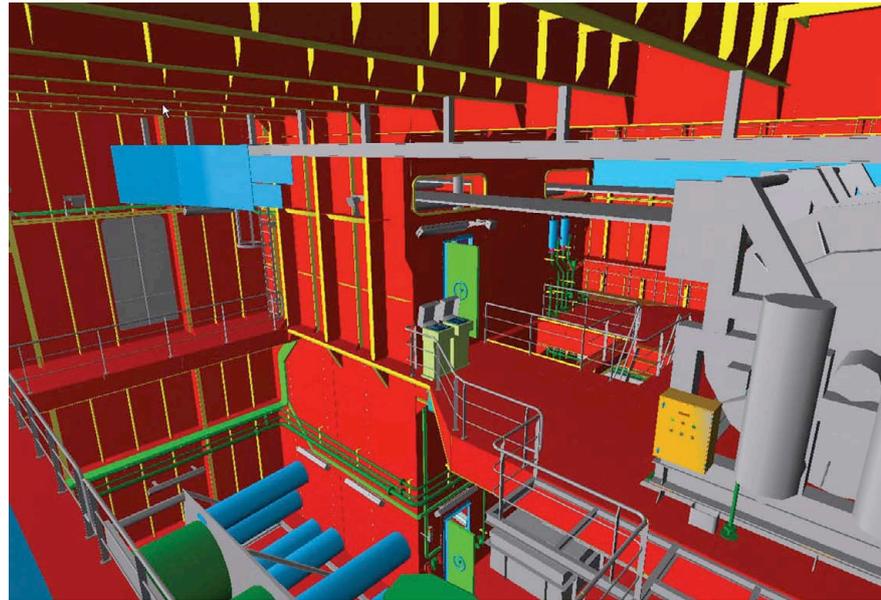
"We hear our customers' preferences. Every two years we meet with our key customers to talk about what can be improved and what is working, so essentially some developments are customer driven", says Antonio Valderrama, area sales manager, Sener.

The significant changes in the module include that it has a modern and intuitive graphic interface, something essential in the 2D drafting modules. There are enough commands at the fingertips, both in the blind menus and in the pop-up menus, opened from every entity.

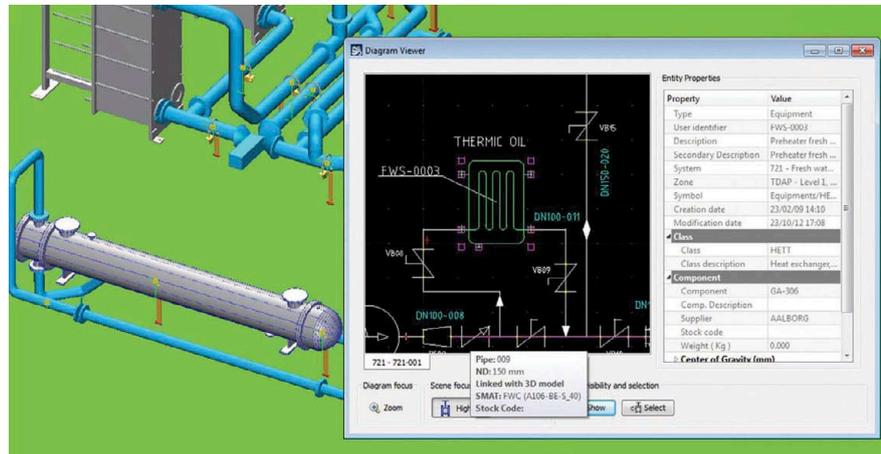
The module allows performing an intelligent management of the symbols, organising them in an unlimited number of library levels, and including commands for the copy, edition, export and import of the symbols.

It includes the possibility to assign SQL instructions to specific symbols, to convert them into drawing boxes and material lists. The execution of the SQL sentences will return real values from the diagram, i.e. the number of some particular fitting already in the diagram, given its class, diameter and material.

Both diagram types include the possibility to edit their logical entities in a tabular mode, through a specific window. This is particularly helpful to apply changes in the attributes to a large number of entities, avoiding the need to search for them visually within the diagram.



CNN Ibañez FORAN V 70 340 Fall pipe module winches



FORAN links 2D with 3D allowing better development of designs

The module has been enhanced significantly the link between the diagrams and the 3D model.

The standards management modules for outfitting (FDEFIN) and electrical (FCABLE) will show the symbols on the screen at the time they are assigned to the existing classes, for a visual association with the logical concepts that will represent (equipment and fitting classes).

It will also be possible to establish logical links between different sheets from the same or different diagrams. FSYSD will control what connects to what when a pipe is cut in a diagram and it will be possible to export and import symbols and diagrams by means of XML files.

"We have embedded the data into the database, which then allows for establishing logical links in diagrams to

parts of a 2D drawing. This information can then be used again in the 3D model. By doing this we have increased a lot of communication between the 2D drawing and the 3D model”, explains Valderrama.

The main areas of the module that will see the latest developments are explained below.

## Symbols

The symbols are managed by means of libraries with an unlimited number of levels, assigning a name, a description and a preconfigured type: symbol, drawing format (box) or material list. They consist of 2D graphical entities, to which they are added to an unlimited number of connection points with their identification and own flow direction.

It is foreseen that the insertion of symbols as part of other symbols, the linear copy of 2D graphical entities and, in general, the use of the typical commands for 2D editions.

The symbols intended for material lists, with SQL instructions embedded, generate on their execution two different types of lists: those for the exhaustive enumeration of the invoked entities (like a complete list of valves with all their attributes) and those for the account of the invoked entities, grouped by predefined concepts (like the total number of a specific type of valve and nominal diameter).

The hierarchical libraries structure allows locking at any given level, either a complete library or a single symbol, to prevent concurrency during its edition.

Regarding the graphic drafting environment, the use of a dynamic grid of reference points, the zoom operated by the mouse wheel and the cursor positioning coordinates, always visible, allow a fast and accurate drafting of the geometry.

## Pipe diagrams

Generated from the ship systems, previously defined by means of the FDEFIN module, they consist of an indeterminate number of separated sheets that display the functional arrangement of the equipment and the fittings, connected to each other by means of pipelines.

With an exhaustive control of the technical characteristics of pipes and fittings, the material specifications

guarantee that the technological attributes are appropriate for the purpose of each line. When needed, pipes and fittings may be completed with user defined attributes.

The equipment addition is intuitive, allowing the incorporation of both own equipment already assigned to the system and coming from other systems (foreign equipment). It is even possible the option to generate new equipment elements directly from the components (equipment catalogue), applying some rules to generate the identification. A simple drag and drop of the component from the list to the graphic area, and the new element is generated and placed in one go.

The FROM and TO symbols, used to identify the pipes connecting diagrams to each other, manage to establish a true logical connection. This allows for the control, for instance, that both diagram points for connection have the same fluid type and material specification.

The relationship between the diagram and the further 3D model has been incremented significantly, so the link between a line in the diagram and a pipe line segment from the 3D model implies that both are locked, and no further change in their attributes (diameter, material specification, fluid or insulation) can be made. The only way to change any of them is by means of the previous break of the link between both entities.

Improvement of the insertion of reducers has been made, by breaking the insertion line

into two parts and updating the diameter of the involved pipe and the previously inserted fittings.

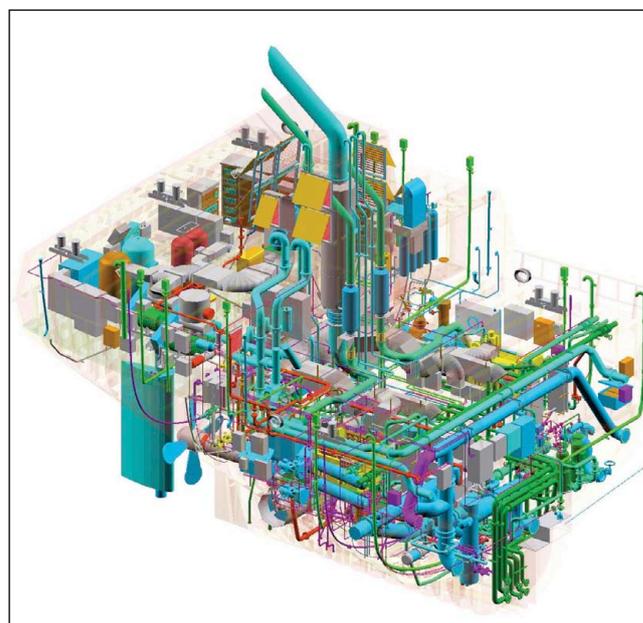
## Electric diagrams

With a very similar behaviour to the pipe diagrams, the electric diagrams' working mode allows them to place electric equipment and fittings in a very intuitive way, and lay down the cables that connect each other in a fast and precise manner. Similar to the previous application (EPOWER), the cable connection goes to the conductor wiring into the different terminal boards of the equipment and fittings.

The right area of the screen is where the pipe diagrams identity tabs are for the Equipment (with the addition of the electrical fittings), Entity Properties, Symbols and Geometry, linking the cables specifically for each for the electric diagrams.

Different than the pipe diagrams, the electric diagrams environment allows configuration of the diagrams in a tree structure, starting in the system list. This is also possible to organise different levels of folders to group diagrams.

It is a module that will enhance the ease of use, which increments the functionality of the diagrams and its integration for the 3D model, and that conveys into a single application. **NA**



FORAN aims to streamline its software

# CFD aides BW installation

Ballast water management poses problems in the design and operation of ships. Computational fluid dynamics offers solutions with design, type approval and trouble-shooting. Tobias Zorn, Jan Kaufmann, FutureShip and Milovan Perić, CD-adapco explain further

**C**omputational fluid dynamics (CFD) denotes collective techniques for solving equations and describing the physics of fluid flow. CFD is now widely known and accepted in the maritime industry, but mostly associated with flows around the hull and propellers, for example in the context of designing more fuel-efficient ships.

However, CFD is in many ways far more versatile than classical model testing.

Ballast water management systems have moved into the spotlight for ship operators with recent IMO regulations, which drive the transition towards ballast water management to curb the spread of invasive species. But, apart from the particularities of the new regulations, ballast water handling may pose challenges for ship operators where the advantages of CFD simulations come into play. The following shows case studies that illustrate problems and solutions taken from industry experience.

## Type approval based on CFD

The IMO “International Convention for the Control and Management of Ships’ Ballast Water and Sediments” requires a ballast water management plan. Starting from the year 2016, all ships will have to base their ballast water management on ballast water treatment.

If this treatment is based on chemical approaches, rapid and effective mixing of the chemical component with the ballast

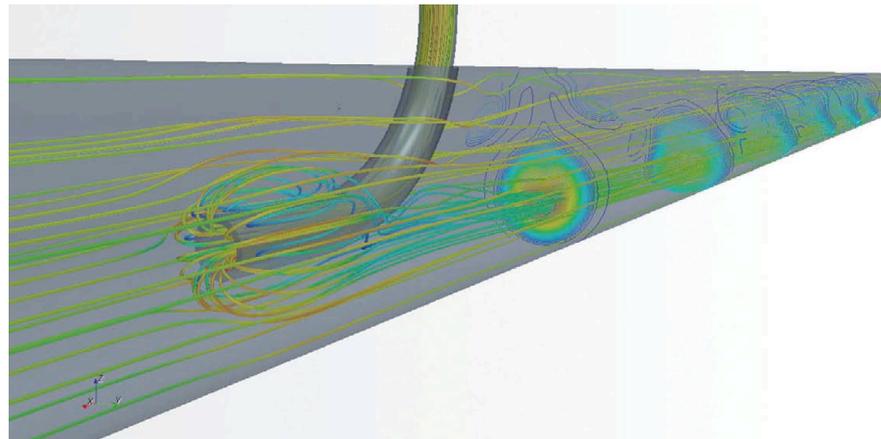


Figure 1: CFD simulates mixing of two fluids in a pipe for type approval

water is vital to achieve a homogeneous concentration of the biocide. For type approval of new systems, simulations can be a valuable tool. In one case, FutureShip simulated the mixing of chlorine and ballast water in pipes during the ballasting operation. The CFD simulations were used to determine the required pipe length of the mixing zone to ensure homogeneous mixing. Simulations showed that the mixing in the initial design was inefficient. Very simple and cost effective modifications of the inlet geometry served to increase the turbulence level significantly with a resulting much shorter pipe length for complete mixing. Figure 1 shows the streamlines and chlorine concentration in the mixing pipe resulting from one such simulation. The authorities accepted the simulations as engineering proof for type approval.

## Ballast water sediments

Sediments tend to collect in ballast water tanks. They reduce the deadweight (payload) and restrict water flow thereby delaying de-ballasting and sediments increase draft resulting in higher fuel consumption. For a Capesize bulk carrier, a ship owner wanted to reduce sediment accumulation and tasked FutureShip with

detailed analyses and suggestions for a re-design in order to minimise sediment settling in the ballast tanks.

In this case, the actual sediments were not modelled. Instead, engineering insight facilitates the simulation. Sediments settle in regions of low water speed, as found typically in areas of recirculation and flow stagnation; these are commonly referred to as dead-water regions. Figure 2 shows sediments in a real ballast water tank. The two-phase (water and air) simulations of flow in ballast tanks first identified dead-water areas corresponding to observed sediment accumulation in the original design. Figure 3 shows computed velocity distribution near the bottom wall. Then various design alternatives for the ballast water tanks explored variations of stiffener spacing and cut-outs. The simulations identified the alternative design with the least sediment settling (i.e. smallest dead-water regions) for future bulk carrier orders.

## Ballast water de-ballasting

A busy coal terminal in Latin America had given strict time limits to de-ballast a bulk carrier at quay. The ballast pump was taking in air during de-ballasting, forcing the crew to stop de-ballasting

Figure 2: Sediments accumulate in ballast water tanks in areas with flow stagnation



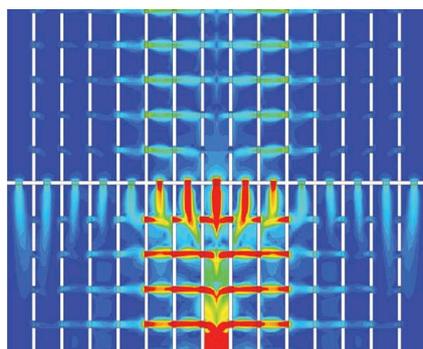


Figure 3: CFD simulation of velocity distribution in ballast water tank close to bottom wall

intermittently. As a consequence, the vessel could not be de-ballasted in the time given by the terminal. The vessel had to leave with 3,000 tonnes of ballast water still in the tanks. As a consequence, 2,600 tonnes of cargo could not be loaded, resulting in €125,000 damage claims and the vessel being blacklisted at the terminal.

A detailed analysis is often the first step in trouble-shooting. Once the problem has become transparent, the solution is straight-forward. In this case, the first step was to simulate the de-ballasting process, setting up a three-dimensional model of the ballast water tanks and mimicking the pump by a prescribed flow rate at the outlet of suction pipe. The outflux was set to the maximum pump capacity. The simulation of the two-phase flow revealed that the water level in neighbouring fields was much higher than in the field with the ballast pump intake during de-ballasting. Figure 4 shows the uneven water levels in various tank sections. The size of the water-flow openings in the longitudinal frames was too small for the de-ballasting rate of the pumps. The simulation provides information about the time-dependent flow rate through each opening and predicts the time at which air begins to be sucked by the pump. The animation of free surface motion and velocity distribution in various cross-sections gives engineers a direct insight into the physics of the

Figure 4: Snapshot of de-ballasting simulation reveal uneven water levels due to insufficient size of cut-outs (pump intake section is almost depleted)

flow and allows an easy assessment of the problem, aiding the design of necessary geometrical modifications.

Based on the analysis of simulation data, more and larger water-flow openings for the frames in the vicinity of the pump were suggested to synchronise fluxes through openings with the pump intake flux. Size and location of the water-flow openings could then be determined such that the inflow toward the pump was above the pump rate, thus avoiding the risk of the pump taking air.

### CFD method

The simulation employed CD-adapco's CFD software STAR-CCM+. This software is capable of simulating turbulent flow with the resulting eddy formation and turbulent mixing, as well as multiple fluids with resolved liquid-gas interfaces. It is able to capture all the important physics for the analysis of ballast water flows as presented here.

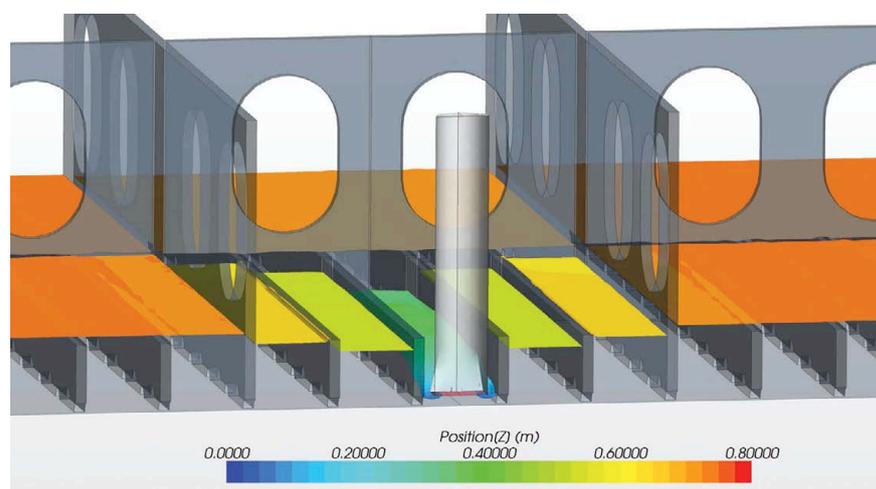
The solution method is based on conservation equations in integral form with appropriate initial and boundary conditions. The solution domain is subdivided into a finite number of control volumes, which can be of an arbitrary polyhedral shape and are typically locally refined in regions of rapid variation of flow variables. The time interval of interest is also subdivided into time steps of the appropriate size. The governing equations contain surface and volume integrals, as well as time and space derivatives. These are approximated for each control volume and time level using suitable finite

approximations, leading to an algebraic equation system which can be solved efficiently on a multi-processor computer.

The flow is assumed to be governed by the Reynolds-averaged Navier-Stokes equations. Turbulence effects can be accounted for by a variety of models, from the simplest eddy-viscosity type models ( $k$ - $\epsilon$  or  $k$ - $\omega$  models are typically used) up to the Reynolds-stress models. The continuity equation, momentum equation, and between two and seven equations for turbulence properties are thereby solved. Large-eddy simulations, which model only the small-scale turbulence and resolve large-scale eddies, are also possible.

Multi-phase, multi-component systems (water-air or water-chlorine in the applications shown here) can also be simulated. The spatial distribution of the phases (liquid and gas) is obtained by solving an additional transport equation for the volume fraction of each additional phase. To accurately simulate the convective transport of immiscible fluids, the discretisation must be nearly free of numerical diffusion. For this purpose, a special high-resolution interface-capturing (HRIC) scheme is used, providing a sharp resolution of free surfaces and allowing simulation of flow with trapped gas bubbles in liquid or liquid blobs in gas.

CFD simulations have proven to be a versatile and powerful tool to support the design and operation of ballast water management systems. The combination of advanced computational software and expert users yields detailed insight and reliable answers. *NA*



# In pursuit of the Arctic

Record minimum ice cover observed in the Arctic Ocean this year is rendering the far North an emerging world of water. While the Arctic will have frozen winters for years to come, the potential for ice-free summers is approaching more rapidly than previously forecast



*Kapitan Sorokin* class ice breaker, the 15,000dwt, 132.4m long ship breaking through the Arctic ice

Internationally, the central Arctic Ocean is surrounded by coastal states that have a special obligation under the United Nations Convention on the Law of the Sea (UNCLOS) to cooperate in its management. Further complications arise from the large and growing Exclusive Economic Zones (EEZ) of coastal states, meaning that the Arctic is largely covered by national rules, yet the high seas are governed through IMO rules and standards. The International Seabed Authority will also have some jurisdiction on the seabed that is not part of the extended continental shelves at this time. As opportunities arise for Arctic ventures, challenges will arise for international Arctic Communities, as well as proponents. Dealing effectively with ice covered waters will continue to be a priority for marine navigation.

The Canadian Government has made the Arctic a priority through its Northern Vision and therefore all eyes are on Canada as it takes steps towards developing the potential that is there.

The Northern region of the Arctic is not only special in that it is distant, cold and difficult to access, it is special in its people, its ecosystems and in its operating context.

The traditional subsistence lifestyles of the people in this region have changed dramatically. Settlements are small and sparse with little infrastructure support. Roads are almost nonexistent, with only about 25 airstrips in all of Nunavut, a new Canadian Territory established in 1999. Hence, the marine route is very important for the supply of communities' every need as well as for development and tourism. In order to make efficient and safe use of this marine route, there is work that needs to be done on the systems and equipment that will provide access to the Arctic.

## Arctic shipping routes

Accessing northern communities and areas of interest is far different than simply crossing the Atlantic Ocean. There is a need for significant domain awareness, especially about the ice. As implied in earlier paragraphs, the Arctic region is

poised for greater regional significance as the polar ice retreats in coming decades. A major change will be an increase in shipping traffic during summer months. Commercial activity from oil and gas, mining, adventure tourism, and government funded science and research activities will drive other needs for access. The Arctic is largely isolated, vast, and environmentally extreme, thereby making shipping routes for commercial traffic increasingly important. Akin to an Atlantic crossing by using the 4-5knots flow of the Gulf Stream to assist in time and fuel consumption, an Arctic crossing requires a clear understanding of a vessel's ice capability and an appropriate route.

Wherever the ice is mobile (rather than landfast) it will occur as floes of various sizes and thickness, and in various concentrations. Depending on visibility, vessel characteristics, and navigator skill, a ship can normally avoid ice contact in less than 2-3/10ths ice concentration at normal open water operating speeds, though the risk of high speed impacts



North West passage route. Courtesy of Arctic Economics

may lead to a voluntary speed reduction. As concentrations increase, contacts will become more frequent. In 9+/10ths ice concentration, the ship is essentially in continuous icebreaking mode, with speed limited by icebreaking resistance matched to ship power.

Flexural and crushing strengths are important risk factors for an ice-strengthened vessel. Impacts with hard ice (higher strength) are more likely to cause damage than those with softer ice. All types of ice may decay in summer conditions, reducing their strength considerably. This is a very important consideration in setting ship strengthening requirements for seasonal operations. Thus, any ice type that may exist along a route should be considered to have its full winter strength.

It is the operational context that is of significant interest to BMT Fleet Technology. For the past 25 years the organisation has had a long and productive history related to arctic engineering and arctic technology developments. These developments have been a cornerstone of many collaborations and partnerships that have stayed in step with arctic development in the past quarter of a century. One of these collaborations has been with the Memorial University of Newfoundland (MUN) in St. John's, Newfoundland and Labrador, Canada.

BMT is one of five industry partners involved in the Sustainable Technology for Polar Ships and Structures (STePS2) project at MUN. STePS2 is a US\$7.2 million five-year applied R&D project, focused on developing tools to design ships and offshore structures for year-round Arctic operations.

Dr. Claude Daley, professor of engineering in the Ocean and Naval Architectural Engineering (NAE) Group at MUN and Principal Investigator of STePS2 states that Year-round Arctic operations of tankers, ice management vessels and structures present significant technical and practical challenges. The NAE Group aims to improve design and assessment methods, which they believe can have a significant effect on whether Arctic oil and gas projects are economically and environmentally viable.

One of the novel aspects of the STePS2 project is the scale of the laboratory tests. In addition to an extensive set of small tests, STePS2 is testing full scale ship structures with real ice in several large static (Figure 2) and dynamic (Figure 3) lab experiments.

This strategy of conducting controlled full scale tests in a lab setting has many advantages over actual field testing, in terms of costs, safety, control and repeatability. The large Double-Pendulum impact apparatus shown below in Figure 3 will be capable of creating an 8m/s ice impact event, with

enough force to severely damage full scale steel ship structural panels.

## Cold weather material requirements

Arctic and cold region materials research continues in an effort to understand and advance the current state of practice and performance of structural steels and weldments deployed in cold weather operations. In the design of a ship structure or mechanical system, the properties of material in their intended operating conditions must be considered. While steel yield and ultimate strength increase with decreasing temperatures and increasing loading rates, two important factors associated with Arctic structure operations, the same cannot be said for steel toughness. In the design of a structural or mechanical system intended for Arctic operations, the hull and deck machinery need to be designed to accommodate these factors.

For example, the material selection for the hull structure of an ice strengthened ship that often requires thick structural members to preclude local buckling, must accommodate low operating temperatures and ice impact loading. Through life the potential for plastic deformation (pre-strain) and the development of notches, cracks or corrosion features on the hulls must also be considered to ensure that the design is damage tolerant. Figure 4a illustrates the well-known ductile to brittle transition behaviour for steel with decreasing temperature that can be characterised using any one of a range of toughness tests. The effects associated with changes in the other design factors (loading rate, notch sharpness, section thickness, pre-strain) on the toughness to brittle transition are described in the Figures 4b through e).

It has been traditionally observed that steels which are produced with higher strength generally have lower toughness than their lower strength sister steels for the same manufacturing process. This observation is anecdotal and commonly reported; however, the effect of increasing steel strength cannot be easily related to a change in the toughness transition curve as has been done for other factors influencing toughness. This is illustrated in the graphs

below. The implications of varying levels of toughness can be directly related to the ability of the structural or mechanical system to tolerate damage or degradation through life. As such, developing and extending an understanding of toughness in Arctic operations directly impacts the prevention of marine casualties and thus protection of the environment.

**Arctic services**

The changing climate conditions and overall warming in the Arctic is allowing oil and mining companies to tap into previously inaccessible reserves. The increased interest in natural resources in the Arctic, coupled with the opportunity to access shorter shipping routes like the Northern Sea Route and the Northwest Passage, means the demand for tactical ice information for navigation in the Arctic has never been more vital. The IMO is currently redefining the Polar Code to ensure tighter controls on what types of ships can travel in the Arctic and is setting other rules for operations to improve safety.

The provision of ice information through the Canadian Ice Services (CIS), a branch of Environment Canada, is paramount to this safe and efficient marine travel in ice infested waters. An employee at CIS states that there are currently twenty nations who operate a national ice service, where

experienced ice analysts and forecasters use a variety of observational methods to determine ice conditions in navigable waterways. These observations range from in situ reports to remotely sensed data and form the basis of a suite of ice information products, primarily ice charts, for the marine community. Ice charts represent the best analysis of ice conditions in a region at a particular time and provide mariners with information on ice extent, stage of development, concentration, and the form of the ice. The increased availability of Synthetic Aperture Radar (SAR) satellites, like the RADARSAT series, provides monitoring capabilities in nearly all weather conditions. When coupled with cloud free visible and infrared satellite imagery, a comprehensive picture of the Arctic is achieved.

The growing demand for better marine forecasts in the Arctic has led to an increased emphasis by the oceanographic community on improving sea ice models in these remote regions. Understanding and predicting what ice conditions will be like in the future is not only extremely important for tactical shipping, but is a key input to global climate models and numerical weather prediction.

Today, the Arctic Ocean is emerging as the next great ocean frontier causing excitement and environmental concern

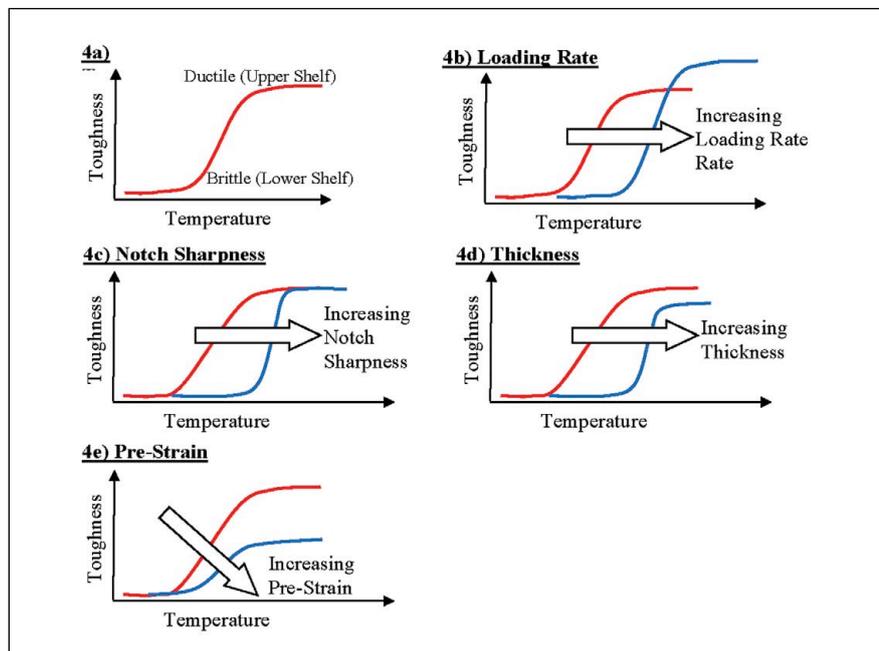
at the same time. Perhaps akin to the days of the Klondike – “there is gold to be had in the north” – the untapped natural resources of the Arctic are attracting the gold-rush seekers, oil and gas producers, the environmental groups, defence and security, and the adventurers. However, the associated risks with a rapid increase in Arctic traffic must be duly considered in order to avoid an environmental disaster like the BP Gulf oil spill of summer 2010 or *Exxon Valdez* grounding of 1989. Such a disaster in the Arctic would cause unprecedented damage and severe ecological impact, which has never been seen before. Furthermore, the Arctic is especially vulnerable to the effects of global warming and is the most prevalent litmus test of events to come. Climate models predict much greater warming in the Arctic and within our lifetime it is expected that the summer Arctic may be ice free.

Nevertheless, we cannot escape the fact that commercial shipping in the Arctic is fast becoming a reality and sea traffic across the northern sea route will increase rapidly over the coming years. Bringing southern ways of life to the northern communities will be no mean feat and seabed exploration must be able to transit safely through the harsh and unforgiving ice environment. The question is: is industry ready for this engineering pursuit? *NA*

Marty Taillefer, marine products, business are lead, BMT Fleet Technology



Effects of extreme temperatures on steel structure



# Articulated LNG carriers

Transportation demand for natural resources from ice-covered regions, specifically the Russian high Arctic, is quickly becoming to reality. John Dolny, of the ABS Harsh Environment Technology Center explains further

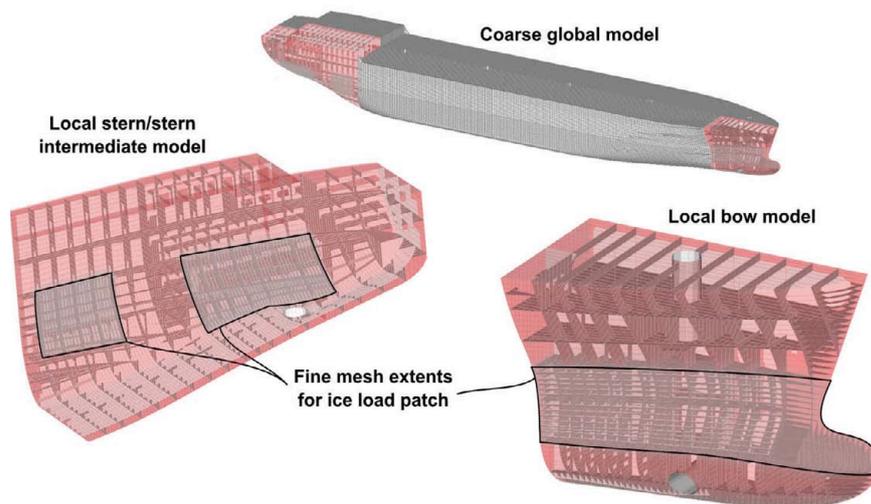
Potential natural gas development in the Kara and Barents Seas, where the marine industry has limited operating experience, requires technology developments for Arctic shipping transportation solutions. Ice strengthening requirements contained within classification rules and other standards provide a basic minimum level of structural strength for ice-going ships.

As vessels of novel design and unprecedented size operate in unfamiliar and harsh natural environments, an increased level of structural performance understanding is sought by prudent shipbuilders and operators. The operational scenario-based direct design method is an attractive option to complement ice class rules. This methodology can address the added structural risks from adverse environmental and operational conditions.

Class society ABS and the Korean shipyard Hyundai Heavy Industries (HHI) collaborated in a joint development project (JDP) of an Arctic liquefied natural gas carrier (LNGC) capable of operations in the Russian Arctic region. Specifically, shipping routes linking the Yamal gas field prospects to European and North American markets were considered.

Functional requirements and basic design concepts for the target vessel were established, including adoption of a double acting system (DAS) concept with a conventional bulbous bow hull form. The ice belt region was designed to consider the stern first operation in heavy ice.

The primary design ice class is ARC6 of the Russian Maritime Register of Shipping (RMRS) Rules. With regard to ice strengthening, the stern area is treated as if it were the bow of a conventional icebreaking vessel. The Baltic Ice Class 1A requirements of the Finnish-Swedish Ice Class Rules (FSICR) were applied to the bow structure to allow for normal operations ahead in light ice conditions.



Finite element models showing the fine mesh extents

Two primary objectives of the JDP were to evaluate different ice load modelling approaches for the derivation of scenario-based ice loads and to evaluate the structural integrity of the vessel subject to the derived loads. Various operational profiles were investigated and applied to determine design ice load parameters for the Arctic LNGC specific to the interaction scenarios established during a Hazard Identification (HAZID) exercise. The first modelling approach, provided by Krylov Shipbuilding Research Institute (KSRI), was developed in line with Russian industry practice and reflects the successful service experience of the Russian Arctic fleet. Since this vessel is intended for Russian Arctic operations and is designed to the RMRS ARC6 ice class, this was a logical starting point for the direct calculation of ice loads. An alternative approach explored during the project is aligned with the methodologies inherent to the International Association of Classification Societies (IACS) Unified Requirements for Polar Ships (Polar UR). The Polar UR is a harmonised system of ice class rules adopted by all IACS members and represents the latest

industry standard for the next generation of ice-strengthened ships in Polar waters.

## Modelling approaches

The KSRI approach follows a general algorithm to calculate ice load parameters (pressure, load height, line load and force) according to a base dangerous service condition (BDSC) specific to the vessel's selected RMRS ice class notation.

The BDSC provides several combinations of ship speed and ice thickness. Exceeding these conditions (above the curve) is presumed to present a risk of potential ice damage. The calculation algorithm is fundamentally based on Kurdyumov and Kheisin's velocity dependent hydrodynamic model for local contact pressure coupled with Popov-type collision mechanics. The Popov mechanics, which have been widely adopted within various ice-ship interaction models (including the Polar UR), simplify the collision to a single degree-of-freedom problem.

Kurdyumov and Kheisin's hydrodynamic model of solid body impact against ice is based on a series of drop tests of spherical steel castings onto ice. The

experiments, dating back to the 1960s, provided some of the earliest insight into ice failure during indentation. During the experiments, a thin intermediate layer of pulverised ice, described as “pasty or powdery”, was observed between the steel casting and an area of cracked and flaked (less broken) ice. This layer was assumed to take on both viscous and plastic properties. It was postulated that the thickness of the fine intermediate layer was proportional to the local ice pressure. The final formulation includes a coefficient dependent on ice crushing strength that is calibrated to represent full-scale data.

On top of the ice crushing formulations, a force limiting flexural failure model is imposed which essentially matches the ‘beam’ strength of the ice to the downward force component from the hull. It is important to note that the load parameters are normalised by the ratio of instantaneous ship speed to the initial collision speed normal to impact direction. The assumed normalisation functions were developed through experimentation with a fit of theoretical expressions. The concept here suggests that each load parameter reaches its peak value at different times during the impact. For the situation where the flexural force limit is less than the maximum crushing force: the pressure, load height, and line load are recalculated according to these normalisation functions. The ice strength parameters assumed in the KSRI model (e.g. crushing strength and flexural strength) are formulated as functions of ice thickness and are regulated according to the BDSC condition.

As an alternative approach, the model, which forms the basis of the IACS Polar UR was also explored in this project. This model adopts the philosophy that the design ice load can be rationally linked to a specific ship-ice interaction scenario. The selected design scenario for the rules is a glancing impact with a thick ice edge (wedged-shaped). The model incorporates the same Popov collision mechanics as in the KSRI model.

An energy balance is established between the initial effective kinetic energy of the ship normal to the impact and the energy expended in ice crushing. The crushing energy is expressed as the integrated normal force over the penetrated depth into the

ice. To relate the force to indentation, a simple process pressure-area model is assumed independent of impact velocity. This description of local contact pressure is one of the fundamental differences between the Polar UR and KSRI approaches. The concept of the pressure-area relationship originates from full-scale ship-ice impact trials where high pressures were observed to be surrounded by lower pressures, and as the nominal contact area grew, the average pressure decreased.

Several assumptions are made in the Polar UR to codify the problem into an appropriate series of rule formulations. One such assumption is the idealised geometry of the ice as a wedge-shaped edge. However, the model can be adapted to permit the use of a variety of contact relationships. In an effort to compare with the KSRI model in a consistent manner, a rounded ice edge is considered. The parabolic shape of the resulting normal contact surface is translated to a rectangular patch, then further reduced, maintaining a constant aspect ratio to account for load concentration as ice edges spall off. Maintaining the normal force, the average pressure in the patch rises as a result of the reduction.

These same load patch shape translation and reduction methods are adopted in the Polar Rules for the wedge glancing collision and tailored here for the rounded edge collision. A similar flexural force limit is implemented into the Polar UR model compared to the KSRI model; however, slightly different coefficients are selected. Nominal ice thickness, ship impact speed and ice strength parameters are assumed in the rules and represented as class factors. In the model adopted for this study, these factors may be adjusted according to the user’s preference.

### Structural assessment

In addition to evaluating ice load modelling approaches and estimating load parameters, performance of the hull structure is also of critical importance. Two common methods include numerical simulations (i.e., finite element analysis) and analytical approaches (e.g., the structural limit states which form the basis of various ice strengthening requirements and grillage analysis methods). As part of the JDP, a nonlinear FEA procedure was applied to evaluate the hull

structural integrity subject to the scenario-based ice loads.

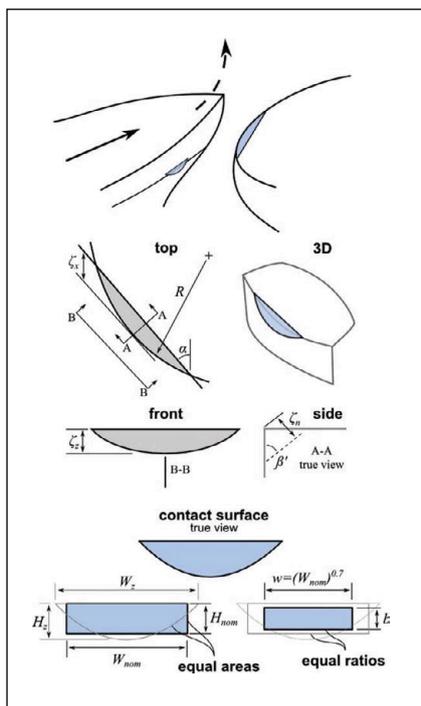
In order to achieve realistic numerical results, a fairly detailed structural model is necessary. All plate structures (e.g., side shell, inner skin, webs, stringers, deck plates, etc.) and stiffeners/framing members are modelled using shell elements with refined mesh densities in the vicinity of the load patch. The steel material properties are modelled using simplified constitutive relationships such as elastic-perfectly plastic (EPP) or elastic-linear plastic (ELP) continua.

Once the finite element models are developed, the ice pressure patches calculated from the loading scenarios are applied incrementally to their respective local fine mesh model with iterations performed during each load step until the solution convergence criteria is met. To determine the limit load of particular structural members, load/deflection curves are examined. The limit load is independent of the loading history. Rather, it is an analysis of the structural response, which identifies a threshold for an external load. Several different approaches exist to estimate the limit load acceptance criteria for a given structure. The scheme for the definition of ultimate pressure (limit load), as recommended by KSRI, is the intersection point of the tangent line at five times the yield point and the tangent line to the elastic region. The results of this structural assessment procedure can be used to justify alternative framing configurations or increased structural geometries to mitigate the risks associated with the ship-ice interaction scenarios.

### Future work

This project explored several impact scenarios, but many more potential non-standard ship-ice interaction scenarios exist. Close pack pressure on the mid-body structure is one example of a dangerous situation, which may prove especially critical to the containment systems of large LNGCs. The current ice strengthening requirements in the RMRS Rules, ABS Rules and the Polar UR do not explicitly regulate ice compression loads. Therefore, direct design methods are currently recommended to address this issue.

It should also be noted that the current RMRS Rules do not allow the use of the



Glancing collision with a rounded ice edge and load patch shape translation

bulbous bow for ARC6 ice class vessels. The structural performance of the bulbous bow in heavy ice conditions was one of the hazards identified during the HAZID study, and this requires further investigation. Greater attention should also be given to the integrity of the cargo containment systems subject to high-speed ice impacts in the mid-body regions. The primary focus of this project was bow and stern impacts simplified to quasi-static loads to investigate the hull structural integrity. For higher-speed collisions, explicit dynamic finite element methods may be employed to model the collisions coupled with the dynamic response of the hull structure and integrated cargo containment systems.

### About the authors

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discussion, insight and contributions to the development of the Polar UR ice load model. Gratitude is also given to Dr. E. Appolonov and the Krylov Shipbuilding Research Institute (Russia) for the explanations and open dialogue regarding the Russian approach to ice modelling. The views expressed herein are those of the authors and are not to be construed as official views of ABS.

\*Please note this article is a condensed version of a technical paper presented at the 2012 Conference on Ship and Offshore Technology - Ice Class Vessels in London, UK. The full conference version contains detailed derivations and additional in-depth discussion.

Dolny, J., Yu, H., & Oh, H. K. (2012). Ice load assessment and nonlinear FEA for the development of a large arctic LNG carrier. RINA International Conference on Ship and Offshore Technology - Ice Class Vessels. London, UK. [NA](#)

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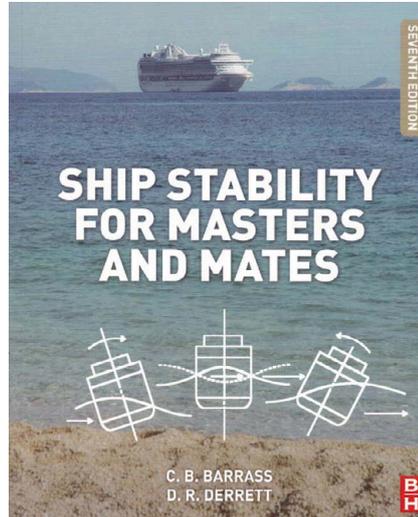
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## Ship Stability for Masters and Mates

Written by C. B. Barrass and D. R. Derrett, published by Butterworth-Heinemann, Elsevier, Oxford, UK, as a softback, 2012, 581 pp. ISBN 978-0-08-097093-6, £49.99.

This is the seventh edition of this established and well regarded book, the first edition appearing in 1964 (Stanford Maritime Ltd) and the sixth in 2006

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have been deleted and nine new chapters introduced. In all there are 56 chapters and seven appendices (including one with advice on how to pass examinations in maritime studies). The latest regulations are covered and the latest examination papers for chief mate and officer on watch courses. The data on ships delivered and on ship groundings since 2006 are given.

Although the title refers specifically to stability the book covers from definition, trim calculations and hydrostatic curves. Also one chapter deals with rolling, pitching and heaving motions and one with synchronous and parametric rolling of ships.

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[www.rina.org.uk](http://www.rina.org.uk)

## May 6-9, 2013

**OTC**, international conference, Houston, USA.  
 E-mail: [OTC@experient-inc.com](mailto:OTC@experient-inc.com)  
[www.otcnet.org](http://www.otcnet.org)

## May 8-9, 2013

**Design and Construction of Super and Mega Yachts**, international conference, Genoa, Italy.  
 E-mail: [conference@rina.org.uk](mailto:conference@rina.org.uk)  
[www.rina.org.uk/super\\_yacht](http://www.rina.org.uk/super_yacht)

## May 11-14, 2013

**IMDEX**, international conference, Singapore.  
[www.imdexasia.com](http://www.imdexasia.com)

## June 3-5, 2013

**Third Conference on Ship Manoeuvring in Shallow and Confined Water**, international conference, Ghent, Belgium.  
 E-mail: [conference@rina.org.uk](mailto:conference@rina.org.uk)  
[www.rina.org.uk/ship\\_manoeuvring\\_in\\_shallow\\_water.html](http://www.rina.org.uk/ship_manoeuvring_in_shallow_water.html)

## June 4-6, 2013

**MAST**, international conference, Gdansk, Poland.  
[www.mastconfex.com](http://www.mastconfex.com)

## June 4-7, 2013

**Nor-Shipping**, international conference, Oslo, Norway.  
 E-mail: [tsc@messe.no](mailto:tsc@messe.no)  
[www.messe.no/nor-shipping/](http://www.messe.no/nor-shipping/)

## June 5-8, 2013

**MTB Superyachts**, international conference, Dubrovnik, Croatia.  
[www.coplandevents.com](http://www.coplandevents.com)

## June 12-13, 2013

**Warship 2013: Minor Warships**, international conference, Bath, UK.  
 E-mail: [conference@rina.org.uk](mailto:conference@rina.org.uk)  
[www.rina.org.uk](http://www.rina.org.uk)

## June 16-18, 2013

**Gastech**, international conference, Amsterdam, The Netherlands.  
[www.gastech.co.uk](http://www.gastech.co.uk)

## June 25-27, 2013

**Seawork**, international conference, Southampton, UK.  
 E-mail: [info@seawork.com](mailto:info@seawork.com)  
[www.seawork.com](http://www.seawork.com)

## June 26-30, 2013

**IMDS**, international conference, St Petersburg, Russia.  
[www.navalshow.ru](http://www.navalshow.ru)

## September 3-6, 2013

**Offshore Europe**, international conference, Aberdeen, UK.  
[www.offshore-europe.co.uk](http://www.offshore-europe.co.uk)

## September 10-13, 2013

**DSEI**, international conference, London, UK.  
[www.dsei.co.uk](http://www.dsei.co.uk)

## September 13-22, 2013

**Southampton Boatshow**, international conference, Southampton, UK.  
[www.southamptonboatshow.com](http://www.southamptonboatshow.com)

## September 17-19, 2013

**IBEX 2013**, international conference, Kentucky, USA.  
[www.ibexshow.com](http://www.ibexshow.com)

## September 17-19, 2013

**Advanced Model Measurement Technology for the Maritime Industry**, course, Gdansk, Poland.  
 E-mail: [amt13@ncl.ac.uk](mailto:amt13@ncl.ac.uk)  
<http://conferences.ncl.ac.uk/amt13>

## September 18-21, 2013

**MTB Workboats**, international conference, Athens, Greece.  
[www.coplandevents.com](http://www.coplandevents.com)

## September 24-27, 2013

**NEVA**, international conference, St Petersburg, Russia.  
[www.transtec-neva.com](http://www.transtec-neva.com)

## September 24-26, 2013

**ICCAS 2013**, international conference, Busan, Korea.  
 E-mail: [conference@rina.org.uk](mailto:conference@rina.org.uk)  
[www.rina.org.uk](http://www.rina.org.uk)

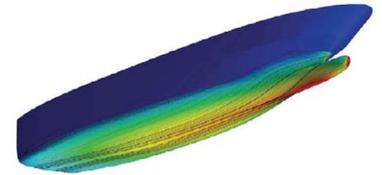
# The Royal Institution of Naval Architects

## Design, Construction & Operation of Super and Mega Yachts



8-9 May 2013, Genoa, Italy

First Notice & Call for Papers



The Royal Institution of Naval Architects will be returning to Genoa, to host the International Conference on Super & Mega Yachts for a third edition.

Whilst we do not expect the rapid growth that the luxury yacht sector has encountered in the last decade, there is no question that the super yacht fleet will continue to grow. Even if the need for a bigger yacht seemed to have reached its peak, the complexity of the designs and the new requirements involved in custom production require innovative solutions.

RINA welcomes papers on all aspects of large sail and motor yacht design, construction, and operation, from designers, researchers, manufacturers, operators, and regulators. Topics may include the following:

- All Aspects of Design - Hull, General Arrangement, Interior, Features etc.
- Operation
- Regulation & Classification
- Powering & Propulsion
- Sea Keeping
- Features, Technologies & Finishes



For more information, visit [www.rina.org.uk/Super\\_Yacht](http://www.rina.org.uk/Super_Yacht)

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by fax on +44 (0)20 7259 5912 or by email: [conference@rina.org.uk](mailto:conference@rina.org.uk)

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XBow model courtesy of Ulstein Group ASA

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