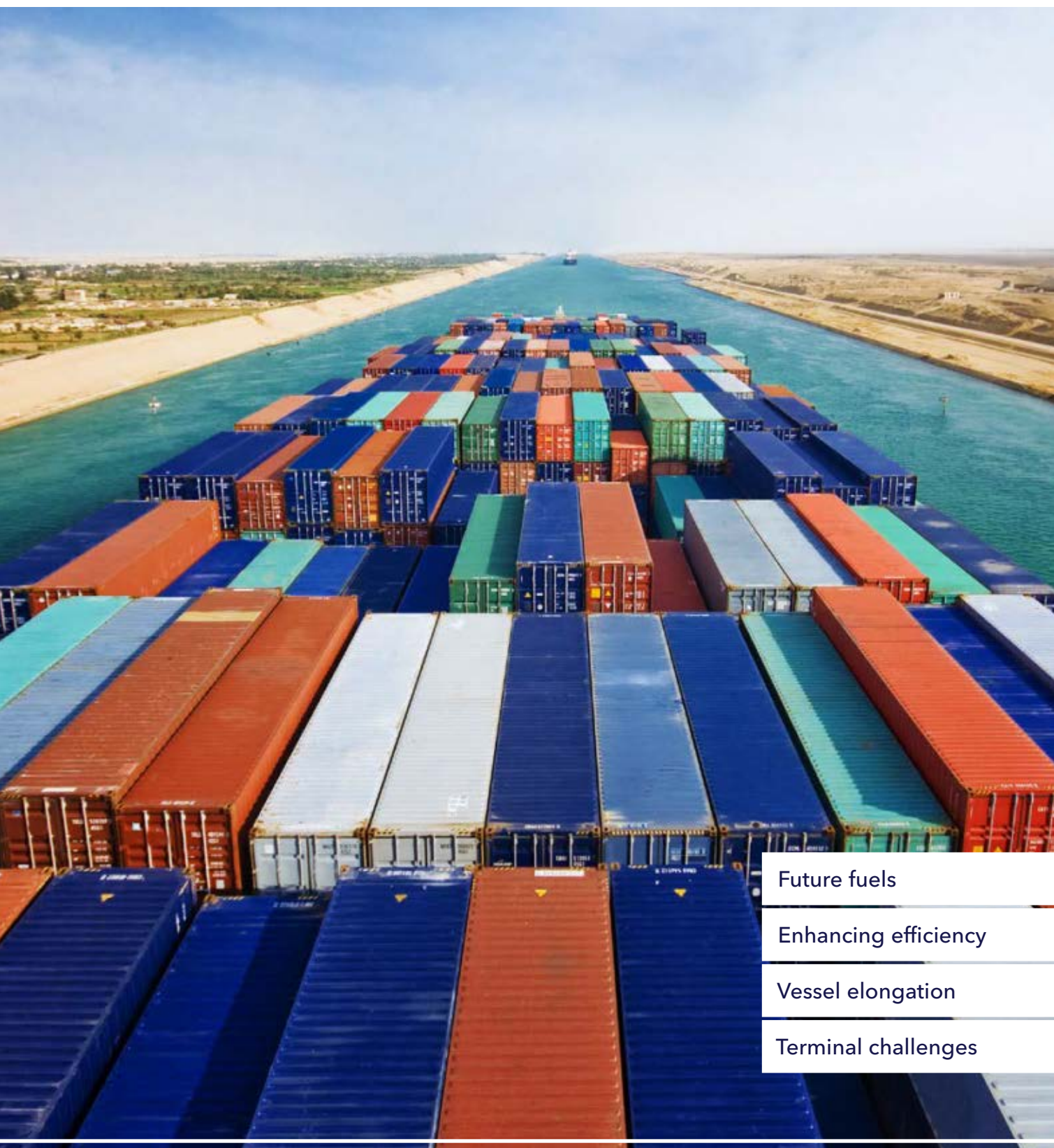


# CONTAINER SHIP UPDATE

2018



Future fuels

Enhancing efficiency

Vessel elongation

Terminal challenges

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## CONTAINER SHIP UPDATE

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## DEAR READER,

These are both fascinating and challenging times for container shipping.

Containers will continue to be the core element of the international exchange of goods. For no other form of cargo transportation have such levels of continuous growth over decades been recorded. Our segment is the backbone of the global value chain and the worldwide economy.

On the other hand, the challenges facing us as the 2020 sulphur cap and many additional environmental regulations draw nearer are unlike any we have dealt with since container shipping began. When planning newbuilding projects, the question whether to opt for scrubbers, distillate fuels or LNG is difficult to answer. DNV GL provides comprehensive guidance and advice to help owners make the smartest choice. One of the options is LNG, and DNV GL has put substantial scientific effort into studying the technical and economic feasibility as well as the safety of LNG as a fuel for container vessels.

Meanwhile the trend towards bigger ship sizes continues. The first vessels in the 23,000 TEU category are now being built, and major owners are increasing their capacity by lengthening or widening existing vessels. Economies of scale are a strong argument, and ports are investing to accommodate these huge ships. The logistics infrastructure of terminals is a key factor to ensure a smooth flow of goods, but the hinterland is not always adequately prepared to handle the sudden peak loads from very large container ships. The industry must weigh its options to find sustainable solutions.

Where economies of scale reach their limits, getting the most out of a vessel's carrying capacity enhances the operational profitability. The updated DNV GL rules for container stowage, along with the completely newly developed software StowLash 3D, are very helpful in maximizing that carrying potential in a safe manner. Other efficiency enhancements continue to be on the agenda, always with an eye on finding the best balance between cost-effectiveness, fuel economy and compliance with environmental restrictions. DNV GL is your best partner in all these projects, and working hand in hand will be an enlightening experience for all of us.

Enjoy reading!

MSC *Filomena*'s old bulbous bow is replaced by a new one at the yard in Dalian, China.

# THE FULL EFFICIENCY PACKAGE

The Hamburg-based shipowner Peter Döhle has modernized its four largest container ships, making numerous efficiency-enhancing modifications which have produced more than satisfactory results. DNV GL contributed its expertise to the project.

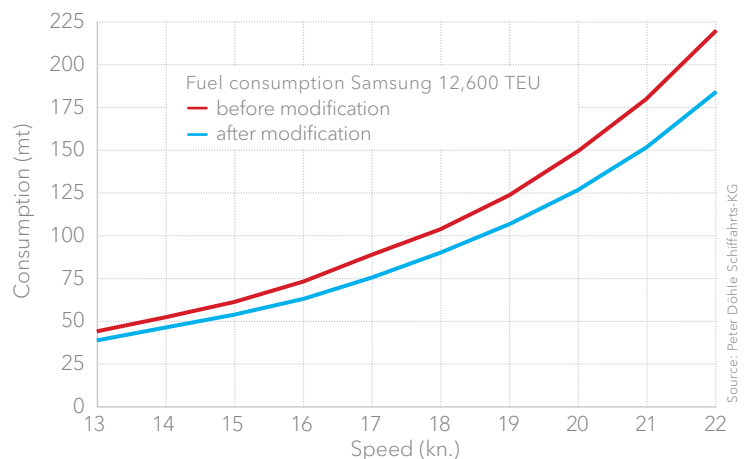
A container ship is never entirely finished: On many occasions during its life cycle, modifications have to be made to adapt it to new market conditions. The F-series of owner Peter Döhle is a good example: The 12,600 TEU ships, christened *Fabiola*, *Filomena*, *Fillippa* and *Faustina*, had been completed by Samsung in South Korea in 2010 at a time when container ships were cruising much faster than today.

A few years later, amid the shipping crisis and soaring fuel costs, "slow steaming" was a relatively easy-to-implement measure. "The ships' original operating profile was no longer appropriate," says Philipp Hesse, naval architect in the newbuilding department at Peter Döhle. "Therefore our performance department began discussions with the charterer, MSC, as early as 2014 to see how these vessels could be made more efficient and eco-friendly," he adds. Since fuel costs are the biggest operational cost item for charterers, tramp and line operators are in the same boat - lower consumption improves a ship's market value.

### Different operational profile

Liaising closely, Döhle, MSC and DNV GL defined a new operational profile and derived a comprehensive package of optimization measures. Since the engine ran with less than optimal efficiency at low rotational speeds, its output was reduced from 60,000 to roughly 41,000 kW by cutting out the turbocharger.

The biggest change, however, was the bulbous bow. "We had to design a shape specifically for lower speeds and a different draught." DNV GL reviewed and approved the designers' proposals, which were then implemented at Chinese yards. Exchanging the bow alone reduces fuel consumption by up to 10 per cent. The stern offered potential for improvement as well: The manufacturer MMG provided a propeller cap which reduces hub vortex losses, saving an additional 2.5 per cent of fuel costs.



“With 13,400 TEU we now play in a different league where we can get additional market share.”

Philipp Hesse, Naval Architect Newbuilding Department,  
Peter Döhle Schiffahrts-KG



During the retrofitting work, the DNV GL surveyor was present at the yard to supervise activities such as pressure testing of the bulbous bow welds. In addition, the shipowner maintained constant contact with the DNV GL head office: “They were always approachable and ready to help in an unbureaucratic manner, which helped us stick to our tight schedule,” Hesse summarizes his experiences. In fact, yard times got shorter as the project went on – while the first retrofit, *Fillippa*, took two and a half weeks to complete in Qingdao, the remaining ships, which were modified in Dalian, were completed within two weeks. Philipp Hesse was present at the yard to supervise the work.

#### Increased loading capacity

Lowering the design waterline was a special challenge that likewise required close collaboration with the DNV GL experts to address the associated stability issues. Validation of the drawings by the classification society resulted in an additional requirement: All in all, around 200 reinforcements had to be welded into the ship’s double-bottom tanks and the passageway below the main deck. But all the efforts proved worthwhile, with the vessels are now able to carry more than 750 additional containers. “With 13,400 TEU we now play in a different league where we can get additional market share,” says Hesse. Since containers can be stacked in eleven rather than eight tiers in the aft section of the ship, it was necessary to elongate the funnel to prevent exhaust gases from entering the boxes. This was accomplished by simply inserting a 4.5-metre block and connecting it with the existing exhaust pipes.

The overall upgrading package not only included efficiency enhancements but also measures to increase operational flexibility. For example, in future the ships will be able to use the

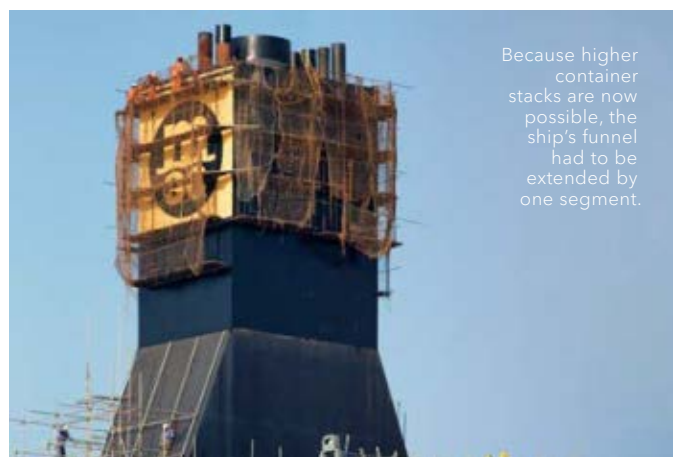
enlarged Panama Canal. “Not a problem as far as the ship’s dimensions are concerned,” says Hesse. But new regulations required modification of the mooring equipment on board. Chocks had to be relocated and bollards exchanged to handle stronger forces.

To enhance the flexibility of the ships and ready them for the future, alternative marine power (AMP) equipment had to be retrofitted. Now the vessels are wired to utilize port-side electricity, which can be supplied via an AMP container placed on the mooring deck in the stern section.

Philipp Hesse points out that the entire package of modifications exemplifies his company’s philosophy: “Peter Döhle takes a long-term perspective on its ships and wants to make them sustainable.” It was a great challenge to implement all the modifications considered “technically, economically and ecologically appropriate” in one project, and to do so within a tight timeframe, he adds. The project was challenging for DNV GL, as well: “This goes to show how much can be optimized even on a modern container ship in a changed operating environment if you take a holistic approach,” says Dirk Lange, Key Account Manager, Business Development at DNV GL. “Our experts have supported many shipowners in retrofitting projects in the past.”

#### Profitable investment

Peter Döhle has profited from many of these experiences in modifications of smaller units. For example, a number of 5,500 TEU ships have received new bulbous bows. All in all, the measures implemented by the company’s performance department on its fleet of 360-metre container flagships have achieved average efficiency increases between 12 and 16 per cent. At a cost of roughly \$1.2 million per vessel, fuel savings alone paid for the measures within about one year. But the next retrofit is already planned: Philipp Hesse and his team have just selected the scrubbers which will enable the four vessels to comply with the stricter IMO limits for the sulphur content in ship fuel from 2020 – another project requiring close cooperation between the owner, the charterer and the classification society. Installation of the systems, which cost \$3.5 million, is scheduled for next spring. “And after that, we will aggressively address the ballast water management issue,” says Hesse. A container ship is never really finished. ■ HSG



Because higher container stacks are now possible, the ship’s funnel had to be extended by one segment.



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# RETHINKING STOWAGE

An innovative method enables much more realistic and precise computation of container stowage and lashing, revealing new potential for loading optimization.

The StowLash software is a true classic: “The basic calculation approach dates back to the 1970s,” says DNV GL expert Mark-Oliver Wobig. That wouldn’t be a major issue, had the conditions on board container ships not changed fundamentally since then: Today’s ships may stack up to twelve containers instead of three, which “naturally places much higher loads on the lashing system,” says Wobig. In spite of many updates over the years, the proven software cannot account for all relevant factors.

Ships have not only become much bigger; cargo securing techniques have evolved as well: Lashing bridges were introduced about 20 years ago, and over the past five years external lashing

has become a quasi-standard, especially on larger vessels, because it allows operators to transport greater weights. This is where the time-honoured system has often shown to be too conservative.

## Capturing dynamic forces

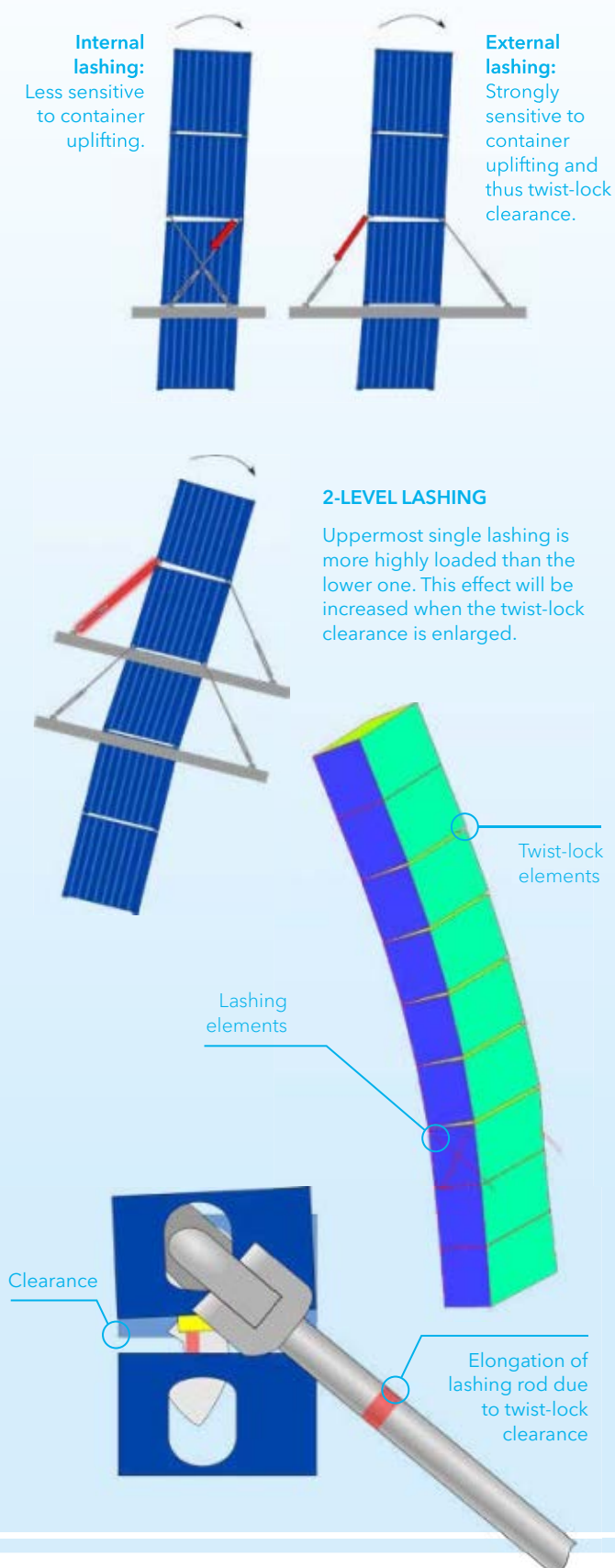
In 2017 the project “Modern Deck Container Stowage” (MDCS) was launched, headed by Wobig. It has developed a new StowLash software generation which uses the finite elements method to calculate the forces acting upon the containers and lashing equipment much more realistically, thereby bringing the quality of lashing force calculations to an entirely new level.



The new software was validated successfully in a full-scale test with six 40-foot-high cube containers.

## MAIN CHARACTERISTICS OF EXTERNAL LASHINGS

Effect of container tilting and racking on lashing rod forces



The previous StowLash software considers the door side and the wall side of each container separately. Transverse forces were split evenly between the two ends of the container to keep calculations simple. The new MDCS method uses a three-dimensional container model which accounts for torsional forces and allows more exact calculation results even when forces are acting on the centre of the container. This means that loads on lashing rods induced by hatch cover and/or lashing bridges deformations, or dynamic forces resulting from twist lock clearance, can now be captured.

### Challenging test

The DNV GL experts spared no effort in validating and optimizing the new method: They tested the computed results on a live object at the premises of the Pella Sietas shipyard in Hamburg. Six 40-foot-high cube containers were stacked on top of each other. Steel cables were attached to put a tensile load on the stack, then released in a controlled condition to simulate the rolling of a stack. Instruments arranged around the container stack measured the forces and deflections acting on it. "This test delivered key insights about the response behaviour of a container stack regarding damping, deformations and forces," highlights Wobig. While the proven StowLash software calculates linearly and was basically developed for the calculation of internal lashing systems, the new, physically more sophisticated software calculates non-linearly and iteratively. It is suitable for calculating both internal and external lashing systems correctly. Innovations in lashing equipment can also be calculated appropriately. For example, so-called gap elements in the new software allow users to define the type of twist-lock being used, and the new computation model accounts for the fact that lashing rods transfer only tension and not compression forces. "Incorporating the interaction of forces in the calculations often reveals potential for optimizing the loading capacity, in contrast to the traditional, conservative approach, especially when using external lashing," says Wobig.

The updated StowLash 3D is the most advanced calculation method available on the market today. An integrated solution based on a validated container model, the software performs rapidly and reliably in spite of the iterative and non-linear calculations.

DNV GL is now finalizing the development of the new software. The related rules will take effect in 2019. ■ HSG



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It is almost a year since MSC Mediterranean Shipping Company ordered eleven new 23,000 TEU vessels, setting a new record for the world's largest container ship by capacity.

Construction of the ships is split between Samsung Heavy Industries, which will build six of the vessels, and Daewoo Shipbuilding and Marine Engineering, which will build the other five. On delivery in 2019 and 2020, they are expected to replace a significant number of 13,000 and 14,000 TEU vessels due to come off-hire in the near future, rather than add to MSC's overall capacity.

The main driver for ordering bigger vessels is to reduce the energy needed to transport each individual container. More energy efficiency lowers costs and helps to minimize CO<sub>2</sub> emissions, which improves profitability and reduces the environmental impact of global supply chains.

They bring other savings too. Each newbuilding can carry around 3,000 TEU more than MSC's current largest ships. Multiplying that by the eleven vessels in the newbuild programme gives an overall capacity in excess of more than two of the smaller ships being phased out. The marginal cost of building bigger vessels is much less than building additional ships.

Can ships grow larger still? According to MSC's manager for the newbuild programme, Giuseppe Gargiulo, the answer to that depends on your perspective. "Technically speaking there are no fundamental physical constraints, and from an operational point of view, a commercial case could certainly be made. The barrier, however, is shore-side infrastructure. We are approaching the maximum size that ports can handle."

The extra capacity on the newbuilds was obtained by extending the vessels' width and increasing the number of tiers on deck. DNV GL played a significant role in the plan approval and confirming the structural integrity of the design by performing the strength calculations using finite element analysis and other tools. Gargiulo notes the vessels are designed to withstand the heaviest North Atlantic storms.

### Propulsion efficiency

MSC opted for a single rather than twin engine configuration. Each newbuilding will be equipped with a MAN B&W 11G95ME-C9.5 main engine. MAN Energy Solutions will also supply the vessels' gensets. The engine is distinguished by an ultra-long stroke that lowers the optimum engine speed and allows the use of a larger, more efficient propeller.

The new ULCSs also feature an air lubrication system. An air blower passes tiny bubbles continuously beneath the ship's hull so that, in effect, it is sailing on a blanket of air. Despite the energy needed to generate the bubbles and additional complexity, the reduced friction translates into significant fuel savings and a 10-15 per cent net reduction in CO<sub>2</sub> emissions. A specially designed bulbous bow yields further savings.

While the newbuilds are LNG-ready, they will initially burn conventional HFO and use exhaust gas cleaning systems (EGCS), built and operated to IMO standards, to provide a safe and practical way to minimize emissions. Gargiulo says the approach has been relentlessly pragmatic. "In our view, the global support

## RAISING THE BASELINE

MSC's 23,000 TEU newbuildings not only set a new benchmark in their size, but embody four decades of container ship experience and some new thinking too.



The new ships will be able to carry around 3,000 TEU more than the largest MSC ships today, the vessels of MSC's Pegasus class.

infrastructure for LNG is still lacking, whereas the EGCS technologies provide an immediate solution for meeting IMO's sulphur cap coming into force in 2020." However, he never says never: "We have not ruled out incorporating LNG into our fuel strategy for the future and we remain open to a variety of alternative fuel sources and propulsion technologies."

In another feature targeting emissions, MSC specified that the vessels can cold-iron - that is to say switch to a shore-based power source when in harbour, thereby allowing the on-board generators to be shut down. This eliminates virtually all at-berth ship emissions. The company was an early adopter and strong advocate of shore power ever since the technology was pioneered in California, USA, notes Gargiulo. Its implementation on the current newbuilding programme earned it Shore Power notation from DNV GL.

### Cargo management

While paying careful attention to engine arrangement, propulsion train and hull form is important, Gargiulo warns against becoming obsessed over vessel specification. "Engineers have a tendency to become fixated on individual components. The danger is they lose sight of the bigger picture. The low-hanging fruit for reducing fuel consumption have been picked. In previous decades, savings of 4-5 per cent were possible, but today the improvements are marginal." MSC is increasingly focusing its efforts on cargo



Giuseppe Gargiulo manages MSC's newbuild programme.



Photos: Hasenpusch, MAN Energy Solutions, MSC

management, both at ship and fleet levels, where, says Gargiulo, there are still considerable gains to be made. For instance, devising a better lashing system lets ships carry more containers but perhaps more significantly permits greater flexibility in cargo arrangement.

Empties can be carried on upper tiers, which speeds up loading and unloading. Shorter turnaround times mean vessels can save fuel by steaming more slowly. Stowing containers on higher tiers means the vessel floats higher in the water, which reduces friction. "These sorts of optimization have an indirect but not insignificant impact on fuel consumption. We're approaching the problem from a different angle."

One challenge is that vessels with a larger beam generally have a larger metacentric height (GM). While a larger GM implies greater initial stability against overturning, it can lead to higher lashing forces and shorter rolling periods. MSC obtained DNV GL's LC notation through using special software to calculate these forces and manage the consequences on vessel behaviour. It also fulfilled the requirements for the Route Specific Container Stowage (RSCS) notation, which allows for increased stowage flexibility in certain trading areas and further improves cargo carrying capacity.

### Fire safety

MSC has worked tirelessly on fire safety. Recent years have seen a spate of container ship fires across the shipping industry. MSC

has already significantly exceeded the mandatory SOLAS requirements in relation to this topic. It has invested in advanced early warning systems and installed equipment to control and cool down any fires before they have a chance to escalate. Gargiulo likens the aggregate effect of these adaptations to each ship carrying its own firefighting tug. Apart from reducing the risk to life and to cargo, tackling fires early improves survivability and increases the likelihood of a stricken vessel reaching a safe port under its own steam.

### Fostering innovation

The newbuilds, says Gargiulo, are "the distillation of 40 years' experience". While market dynamics may change every few years, triggered by shifts in the wider economy and global politics, MSC has consistently managed to find ways to adapt its ships and its business to weather these ups and downs.

Gargiulo ascribes this adaptability to the company's hands-on approach to vessel operation. He explains: "When our newbuild teams aren't working on new ships they are involved in the day-to-day issues that arise on existing tonnage. This exposure gives them a better grasp of challenges and the opportunity to notice things that might otherwise be missed."

It results in cross-fertilization of ideas and knowledge spill-over – precisely the conditions needed to spark new ideas. Gargiulo finds it hard to imagine such innovation arising only from reviewing monthly KPI reports on fleet performance.

In this way, the current newbuild programme drew heavily on the experience MSC gained from its 19,000 TEU class ships. Although they have a smaller beam, Gargiulo says much of the know-how was transferable. "Operation of our 19,000 TEU vessels has undergone considerable refinement over time. Most of those improvements are applicable to the 23,000 TEU vessels, so we've carried it across. We are starting from a more advanced baseline."

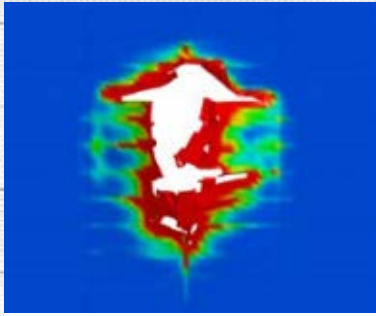
Diego Russo, Principal Surveyor at DNV GL, believes MSC has demonstrated remarkable ingenuity in this newbuilding programme. "Finding solutions to the challenges of building vessels on this scale requires a mix of practical experience and new thinking in order to bring numerous design, operational and commercial demands into equilibrium."

He added that the vessel operator's collaboration with DNV GL emerged from a need to manage and mitigate the risks that inevitably arise from such innovation. "The cooperation between MSC and DNV GL has grown in line with the size and number of new vessels being built in Korea. Everyone involved in the programme – including owner, shipyards, class and other stakeholders – gained valuable experience from the collaboration as they worked towards implementing these innovations, which together set a new milestone in container ship design." ■ KT



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Numerical simulation of a ship impacting the 18,000 TEU VLC at a 90-degree angle at 10 knots.

# THE TANK PUNCH TEST

Innovative technology, a growing supply infrastructure and new international standards have built a strong case for LNG, long considered too hazardous, as a general ship fuel. A recent study looks at the collision safety of LNG membrane tanks.

LNG is the cleanest fossil fuel option available to shipping; further reductions of the CO<sub>2</sub> output can only be achieved with fuels from renewable sources. While LNG carriers have been sailing the world's oceans for decades with a very good safety record, the remainder of the shipping industry and its insurance partners rightly demand clarity regarding the risks of carrying LNG on board, in particular in grounding or collision incidents.

In spite of increased ocean traffic, collisions are much rarer today than they were decades ago, thanks to improved navigating, ship locating and traffic management technologies. But incidents do occur, especially in busy sea areas such as the North Sea or the South China Sea, and container ships are somewhat more vulnerable than other ship types due to their more slender contour.

Because of its cryogenic properties and its flammability in air, LNG requires a storage tank system that remains completely tight in an accident. To find out what would happen to an LNG-powered container ship in a collision, DNV GL, the Hamburg University of Technology, and the French LNG containment system specialist GTT launched a joint research project. The collision risk study investigated a hypothetical 18,000 TEU container ship with GTT Mark III stainless-steel membrane LNG fuel tanks designed

according to the requirements of the new IGF code, which specifies safety criteria for LNG as a ship fuel, including the minimum distance between the outer shell and the LNG tank. Membrane tank systems make the best use of the space available in a ship's hull. Their volumetric efficiency and reduced steel weight can lower the total vessel cost and CAPEX for large tanks compared to Type-C tank solutions.

## Probabilistic risk assessment

The ship under investigation was assumed to trade on a typical route between Asia and Europe. Collision statistics for all ship types along this route were used to estimate the probability and consequences of a worst-case collision impact: over a twelve-year period, the analysis concluded, 470 collisions involving container ships should be expected, and 20 of these incidents would result in a rupture of the inner hull.

A membrane tank system is composed of various layers of insulation and reinforcement materials which are directly connected to the inner structure of the ship and can absorb some of the impact energy in a collision. The ship design investigated had a double-hull width of 2.5 metres distance.



The collision scenario derived from this data was subjected to both numerical and experimental evaluation. Before any mechanical tests were performed, the deflection behaviour of the inner hull was calculated through finite-element analysis assuming the bow of another vessel striking the most critical hull area of the LNG-powered ship at a 90-degree angle - the most forceful type of collision - at a speed of 10 knots. The size chosen for the striking ship was about 30 per cent smaller than the impacted vessel because its sharper contours represent a more critical collision scenario. To simplify the calculations the impacted vessel was assumed to be stationary; hydrodynamic effects were ignored. According to the FEM calculations, outer fracture will occur at a penetration depth of about 1 metre, and inner hull fracture at about 3 metres as the bulbous bow of the impacting vessel hits the container ship.

### Membrane tank flexibility ensures safety

The structure of the GTT stainless-steel tank membrane is of critical importance for the collision behaviour. A grid of evenly spaced knots and corrugations in the austenitic steel sheeting stiffens the tank wall while allowing it to react to the large temperature differences LNG containment systems must withstand. The same structure also acts as an energy-absorbing feature in a collision: the corrugations simply yield to impact pressure by “unfolding”, giving the tank wall additional flexibility. This greatly increases the survivability of these tank systems, which have withstood major deformations in grounding and other incidents without leaking.

To verify the FEM results, a lab experiment was performed at Hamburg University of Technology (TUHH) using a 3.75 by 3.75 metre mock-up of the GTT membrane tank wall welded to a horizontal supporting frame, which assumed the role of the inner hull of the ship. The impact of the bulbous bow was simulated by a spherical steel body moving downwards into the centre of the mock-up. The bulbous bow dummy was rigid enough to resist deformation, which would absorb some of the impact energy.

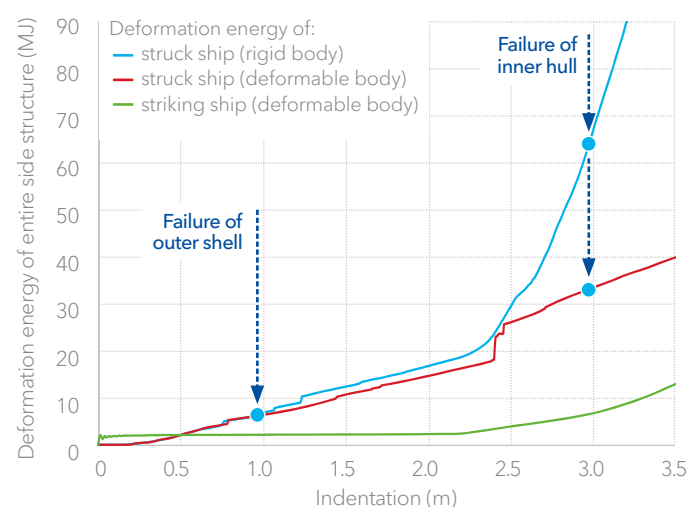
The mock-up was indented by approximately 0.8 metres. On a real container ship with a membrane LNG fuel tank 24 metres long, this would be equivalent to an eight-metre penetration into the inner hull; the amount of impact energy absorbed without rupture would be close to 400 MJ. These experimental results, which were largely consistent with the FEM calculations, cover the majority of historical collision energy values collected for the relevant route.

Some deviations between the test and numerical simulation data occurred during the first run of FE calculations. TUHH is working on fine-tuning the calibration of numerical simulations.

Adding some reinforcements to the ship's side structure near the LNG tanks would further increase collision resistance. By comparison, grounding incidents are less likely to cause major penetration since the double bottom of these large container vessels is more than two metres tall, and historically very few groundings have exceeded this height at which the inner hull would be affected.



Test rig following the impact of the bulbous bow dummy (left) on the membrane tank mock-up, showing the deformation (right).



The deformation energy vs indentation depth graph shows the amount of penetration to expect under realistic collision assumptions.

In the unlikely event of an actual rupture of an LNG membrane tank, the vaporizing LNG could catch fire. In contrast to HFO spills and fires, however, an LNG fire would last hours rather than days and cause no direct environmental damage. On the other hand, an on-board fire with another cause does not necessarily pose a major risk to the LNG system, which is well protected by insulation, safety valves and vent masts. In fact, the most hazardous aspect of using LNG as a ship fuel is bunkering operations.

Membrane-type containment systems have demonstrated their exceptional efficiency and safety on board LNG carriers in more than 15,000 accumulated years of experience without any loss of cargo. Since the LNG containment system is much smaller on a container vessel, the hull surface area vulnerable to a collision is likewise smaller, which - compared to an LNG carrier - reduces the relative risk. ■ AK



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# TOMORROW'S SHIP FUELS

The shipping industry is rapidly reaching a point of no return: Emission limits and, in the more distant future, complete decarbonization will change ship operation dramatically. The question is: How should container ships be built today?

The Paris Agreement aims to limit global warming caused by greenhouse gas (GHG) emissions to less than two degrees. For the shipping industry, the IMO's greenhouse gas strategy (MEPC.304(72)) has set three targets: to reduce CO<sub>2</sub> emissions per transport work by at least 40 per cent by the year 2030 compared to 2008 levels, pursuing efforts towards 70 per cent by 2050, and to eliminate GHG emissions from shipping entirely before the end of this century. These goals promise to be game changers for the transport industry. Climate change is a reality and must be curbed to prevent severe consequences for mankind and nature.

Before, these long-term goals become a pressing issue, the 2020 sulphur cap requires immediate attention; it will be followed by nitrous oxide (NO<sub>x</sub>) and particulate matter emission restrictions, at least in specific areas. The traditional way of propelling ships with low-cost fossil fuels will soon be history.

Land-based energy consumers can replace fossil fuels with renewable energy sources such as wind and solar power quite easily. For aviation and shipping, however, the situation is much more difficult: both modes of transport must carry an appropriate energy supply on each voyage. This severely limits the options available to them. There is currently no alternative to the combustion principle to generate the massive thrust needed to propel a large aeroplane or ship. For a transitional period of one or two decades as the world inches towards decarbonization - or rather, carbon-neutral

renewable fuels - there is no way around fossil fuels as a main energy source on board, specifically for deep sea shipping.

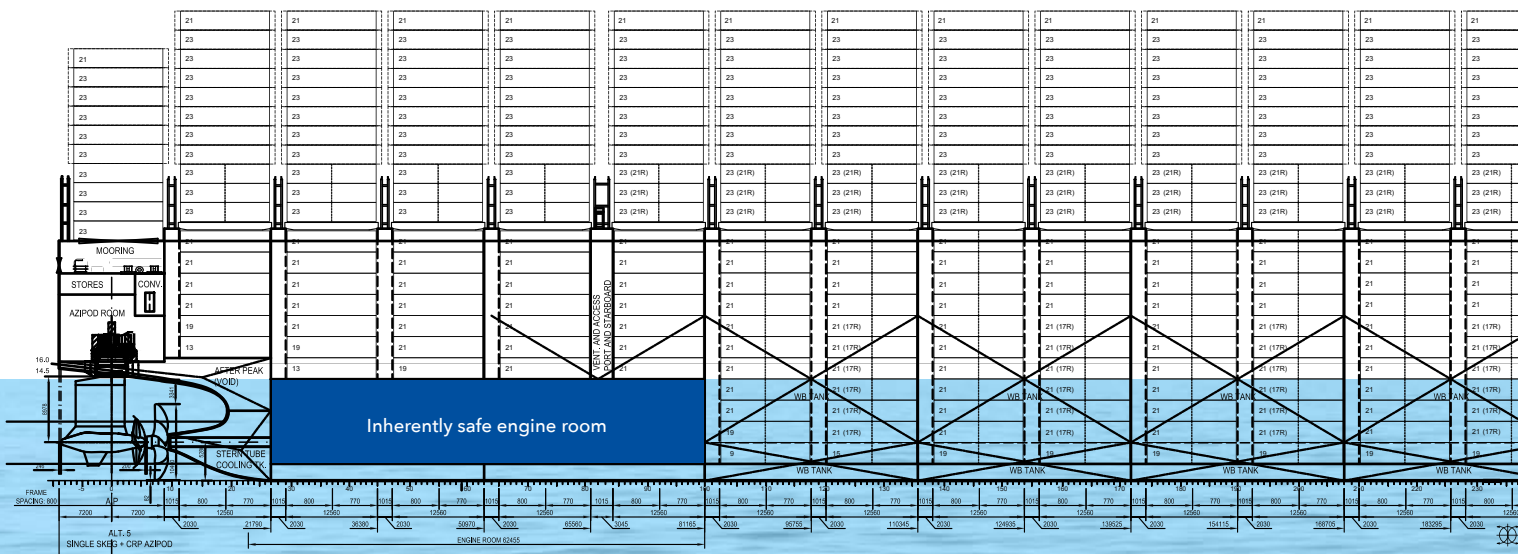
## Go for the most advanced technology

For owners ordering newbuilds today it is essential to plan for the strictest emission limits foreseeable, considering the operating life of a typical container vessel of roughly two decades. Choosing the right fuel and propulsion technology means ensuring that today's newbuilds will be marketable for their entire lifespan. Future emission legislation is unlikely to include any grandfathering clauses for non-compliant legacy tonnage.

There are several factors to consider when making this choice, whether today or at some time in the future. The 0.5 per cent sulphur cap taking effect in 2020 will increase the average fuel costs. Shipowners relying on HFO and scrubbers should bear this in mind - and the fact that open-loop scrubbers are hotly debated and may be banned at least in environmentally sensitive regions at some point. Closed-loop scrubbers, on the other hand, are subject to complex waste disposal requirements.

Furthermore, the IMO NO<sub>x</sub> Tier III limits, in effect for newbuilds in North American Emission Control Areas (ECAs) since 2016, and taking effect in the North Sea and Baltic Sea ECAs from 2021, require additional after treatment of diesel engine exhaust gases by selective catalytic reduction (SCR) systems or exhaust gas

Schematic of the vessel design developed by the PERFECT joint industry project. The LNG fuel tank is located underneath the superstructure.



		HFO	LSHFO/MGO	LNG
Diesel	SO <sub>x</sub>	Scrubber	Compliance	Future-proof
	NO <sub>x</sub>	Tier III: EGR/SCR	Tier III: EGR/SCR	Tier III: EGR/SCR
	CO <sub>2</sub>	High carbon	High carbon	Reduced CO <sub>2</sub> *
Otto	SO <sub>x</sub>			Future-proof
	NO <sub>x</sub>			Future-proof
	CO <sub>2</sub>			Reduced CO <sub>2</sub> (CH <sub>4</sub> slip)*
PERFECT (COGES)	SO <sub>x</sub>		Compliance with 0.1 MGO	Future-proof
	NO <sub>x</sub>		Future-proof	Future-proof
	CO <sub>2</sub>		High carbon	Reduced CO <sub>2</sub> (no CH <sub>4</sub> slip)*

A comparison of fuel and engine types and their emission performance shows the benefits of LNG, especially in a COGES turbine propulsion system. Orange fields represent disadvantages, green fields advantages.

\* Lowest CO<sub>2</sub> of all fossil fuels

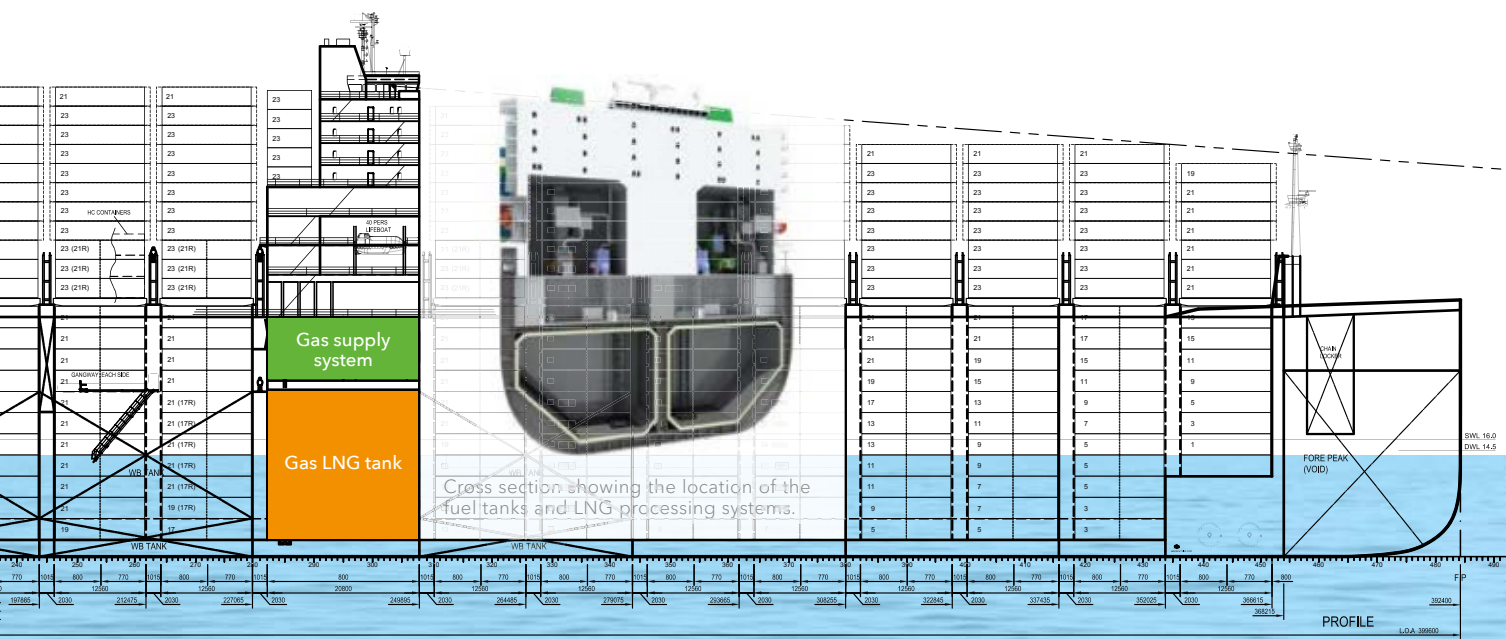
recirculation (EGR) on most engine types. For newbuilding projects, the costs of installing and operating all this pollution mitigation technology are, or will soon be, in the same range as the cost associated with the use of alternative fuels and propulsion systems. In addition, further regulation could be implemented, like limits for particulate matter ('black carbon') emissions which will further increase the costs of using conventional fuels.

The most difficult aspect, however, is CO<sub>2</sub>. The IMO greenhouse gas strategy essentially requires a container ship ordered today to cut CO<sub>2</sub> emissions during its lifetime by 40 per cent compared to a similar vessel operated in 2008. Great strides have been made in energy efficiency enhancements and emission reduction technologies in recent years, from hull and propeller optimization, high-efficiency ship engines, air lubrication and friction-reducing hull coatings to slow steaming and route optimization. All these technologies have made significant contributions to reducing both the emission profiles and the OPEX of container vessels. Emerging technologies such as system optimization with battery-assisted on-board power grids and new propulsion technology as outlined in the PERFECT ship project offer additional opportunities to >



State-of-the-art membrane tanks make the best use of the available space and are safe and highly resilient, thanks to the creased wall structure.

Photos: By Thinfourth [CC0], from Wikimedia Commons, CMA CGM



Computer simulation of the ready-to-build PERFECT 20,000 TEU design. A number of power plant options can be installed. All options use electric propulsion and meet all current and future emission regulations.



Visit YouTube for an in-depth video of the PERFECT ship project.

> further limit the CO<sub>2</sub> footprint. Selecting the best combination of these measures with a suitable fuel strategy can help the industry reach the 40 per cent CO<sub>2</sub> emission reduction goal the IMO envisions for 2030. It should be mentioned in this context that the challenge is somewhat greater for container ships than for other similarly sized vessels because container ships are typically fitted with more powerful main engines with higher emission volumes.

### LNG a favoured option

Taken together, all these considerations make liquefied natural gas (LNG), without doubt the cleanest fossil fuel, look increasingly attractive in view of present and future emission restrictions in general, and the 40 per cent GHG reduction target for 2030 in particular. LNG produces the lowest tank-to-propeller CO<sub>2</sub> emissions of all fossil fuels and is already cheaper per kilowatt hour (kW/h) than HFO. With the supply chain gradually improving and the market volume increasing, LNG prices are likely to drop further. The emission profile of LNG beats all other fossil fuels across the four emission groups (SO<sub>x</sub>, NO<sub>x</sub>, particulate matter and CO<sub>2</sub>). German owners opting for LNG might benefit from government subsidies which are currently being offered.

There are various combustion technologies available for LNG. The diesel principle is efficient but requires exhaust gas after-treatment to meet Tier III NO<sub>x</sub> limits. The Otto four-stroke combustion principle, while slightly less efficient, will comply with current environmental standards without exhaust gas after treatment. Turbine technology is still met with scepticism by the industry because of less-than-satisfactory past experiences. However, advanced COGES implementations are very efficient, free of methane slip, and feature low emission values. Turbines definitely deserve to be reconsidered. DNV GL and various industry partners have performed in-depth studies of COGES ship propulsion technology, with positive results. But even without turbine technology, the efficiency of a reciprocating engine can be increased substantially by installing waste-heat recovery (WHR) systems, which offer a number of benefits on LNG-burning engines, such as reducing the load demand on the auxiliary engines. A well-designed WHR system can recover five to ten per cent of the mechanical power of an engine. DNV GL stands ready to advise customers on proper WHR system design.

### The space question

But there is a downside of sorts even to LNG: its volumetric density is significantly lower than that of diesel, which means that nearly twice the tank volume is needed to achieve the same endurance for a vessel. However, this effect can be compensated at least in part through an optimized system with flexibility in the arrangement. The DNV GL PERFECT study investigated this in

detail, showing that a smart machinery arrangement can allow the container intake to be increased.

Furthermore, as the global LNG bunkering infrastructure improves, containerships may be able to avoid sacrificing container slots in favour of LNG fuel tanks by simply refuelling a bit more often. The optimum tank size should be determined based on the intended trading pattern and bunkering frequency. It should be noted that while the volumetric energy density of LNG is lower compared to conventional fuels, requiring almost twice the tank volume for the same endurance of the ship, its gravimetric energy density is higher, meaning that more payload can be transported.

### Squeezing the GHG footprint

While nobody can safely forecast future fuel prices, the laws of supply and demand continue to apply, and LNG is not an exception, considering the enormous reservoirs still waiting to be tapped. LNG, especially when combined with other state-of-the-art efficiency enhancements, is more attractive than ever as the safest bet for the next generation of container ships – it meets all emission limits relevant for the current generation of ships, its availability is improving rapidly as more bunkering vessels are deployed, and the return on investments in LNG propulsion technology is accelerating and will continue to do so as the technology enters the mainstream. It avoids or at least reduces the complexities of exhaust gas after treatment systems, can be carried on board safely, and will be a competitive advantage for companies whose reputation, at least in part, depends on their environmental footprint.

Once the production of synthetic fuels using renewable energy – usually referred to as ‘Power to Fuel’ (PtOF) and ‘Power to Gas’ (PtOG) technology – reaches an appropriate scale and economic feasibility, LNG-powered ships and their bunkering infrastructure will be fully compatible without requiring any technical modifications. The IMO’s IGF Code provides clear technical guidance, and DNV GL has all the experience and knowledge to assist in its implementation. ■ AK



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# KNOW HOW TO STOW

A new software application allows DNV GL customers to perform individualized route calculations for the purpose of optimizing container stowage.

Optimization is an open-ended story: In the case of route-specific container stowage (RSCS), this applies especially to the parameters of flexibility, cost and time. On its cloud-based platform Veracity, DNV GL now offers its customers the new software app RSCS+ which allows them to calculate route and ship-specific stowage and loads in a simple and cost-effective way within the scope of the revised class notation Route Specific Container Stowage Plus, which was made available in July this year.

Before the RSCS class notation was first introduced in 2013, shipbuilding and lashing rules were always based on a reference route in the North Atlantic only. However, the wind and wave conditions prevailing in that region are often much more severe than in other trading areas. Therefore new safety tolerances were defined for ten standard routes to allow containership operators to transport additional or heavier cargo on deck in those trading areas.

"We also began offering our customers individualized route calculations as a service. However, the entire process turned out to be too cumbersome," recalls Daniel Abt, Senior Approval Engineer at DNV GL. "In view of the fact that container ships are increasingly being deployed on varying trades with varying load assumptions at shorter intervals, the newly developed 'Plus' version of the RSCS class notation offers true added value to our customers."

With the new application, individual route calculations can be performed quickly and easily with a few mouse clicks. The operator simply clicks through the app, enters the route-specific information, such as ports and sea regions, and then receives the so-called Route Reduction Factor. This factor is then entered into the lashing computer to calculate the load. No further approval is required.

"The calculations for long-haul routes are based on the same, recognized DNV GL rules as before; the main difference is that digitalization has made the service much simpler and more flexible for our customers to define their own trading routes," says Abt.

## An advantage for short trips

The RSCS+ notation also ensures greater flexibility for stowing containers for limited short sea voyages. For example, when a vessel arrives at its first destination port in Europe after a long-leg voyage from Asia and begins its so-called collecting trip, its partial draught changes from port to port, often requiring costly, time-consuming container re-stowage. The reason: When the



Good weather conditions may avoid cost-intensive restowing after partial unloading of containers for short sea voyages.

vessel is partially loaded, its metacentric height (GM) rises, causing the ship to be stiffer in the water, and accelerations to increase. Its faster and harder rolling motion raises the loads acting upon the container stacks, which results in a container stack which had been safe now exceeding the permissible lashing forces.

"Repeated re-stowage is a significant cost factor for ship operators," confirms Abt. "But when the sea is calm, it may not be necessary." The new RSCS+ notation accounts for this scenario by enabling a weather-dependent lashing approach. On short legs of up to three days between two ports, applying reduced loads is feasible under calm weather conditions. This means that before leaving port, the operator must evaluate the maximum significant wave height expected during the next five days using data from reliable weather services. "In the event of delays or waiting time on the short voyage, this leaves a forty-eight-hour minimum safety buffer to the intended three-day voyage," Abt explains.

The reduction factor solely depends on the forecasted significant wave height. In this scenario all calculations are performed on board, not online. "Nevertheless, the conditions during the limited short sea trip can be documented in a simple and clean manner using a template and the calculation is run with verified software," says Abt. ■ PL



### DNV GL Expert

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A container ship operator looking to boost the capacity of its fleet has two options: It can order new, larger ships to replace existing tonnage reaching the end of its useful service life, or it can modify existing ships.

Each approach has its respective advantages and disadvantages. To decide, the operator must weigh up the technical challenges, investment required and time needed and balance these against commercial realities and long-term strategic goals. Although lengthening a vessel is a substantially speedier and cheaper method of acquiring extra cargo capacity than ordering a newbuild, it does limit the scope for broader innovation.

MSC Mediterranean Shipping Company recently approached DNV GL to carry out the plan approval and oversee the elongation of a series of 14,000 TEU container ships. The project would see the 366 m long vessels grow by almost 30 m – equivalent to two 40 ft bays – and add around 20 per cent to the ship's nominal container intake at a relatively low cost and with relatively short downtime. The extra length yields around more than half of the additional 2,750 TEU capacity, while the remainder comes from additional deck tiers.

While elongation is an established procedure, successful execution depends on extensive planning to ensure that the vessel's structural integrity is not compromised. The impact of the lengthening on other on-board equipment and services – from ballast water management to fire safety – and their respective SOLAS and MARPOL requirements must also be considered.

#### Strength assessment

But the primary concern is the vessel's longitudinal strength. A ship should have sufficient strength to bear its lightweight, the weight of its cargo, and also the forces which the sea exerts upon it during a voyage. The way these forces are distributed in a vessel's structure is intimately related to its length.

## A LONGER-TERM VISION

Verifying longitudinal strength is a critical part of vessel elongation projects, but is by no means the only technical consideration.

Since the insertion is built to the original scantlings in order to facilitate welding, the additional bending moments on the hull caused by the elongation must be compensated for elsewhere. A longitudinal strength assessment carried out by DNV GL revealed the extent of reinforcements necessary for the MSC project.

These reinforcements took the form of a raised sheer strake – or what could be described as a strength bulwark – built close to the height of the hatch cover level running along approximately 70 per cent of the ship's length. This modification has both local and global effects on structural strength, which must be quantified to ensure they remain below acceptable thresholds. Verifying the global impact was accomplished by performing a full ship finite element analysis. Impact on bow and bottom slamming were also checked and approved during the assessment.

Straking is not the only potential solution but it was chosen for this project as it confers a major benefit: The insertions can be prefabricated as a stand-alone section prior to the ship entering dry dock. This substantially reduces off-hire. However, it does call for increased preparation on board, including the removal of stanchions, chocks and rails etc. It also necessitates increased effort at the planning stage to design new stanchions, as special attention





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must be given to the way they are connected to the top plate to minimize fatigue.

### Environmental performance

In any elongation project, a number of SOLAS and MARPOL requirements must be considered and reassessed to determine if modifications are necessary. These include requirements relating to intact and safety stability, cargo hold ventilation, fire prevention and suppression, and fuel tank protection requirements. For example, lengthening can affect bridge visibility, specifically visible line of sight and blind sectors. This had to be reassessed in accordance with SOLAS V Regulation 22.

Elongation projects generally don't necessitate a recalculation of a vessel's Energy Efficiency Design Index (EEDI). DNV GL ship type expert for container ships, Marcus Ihms, explained: "Lengthening a vessel without changing the propulsion arrangement has a positive effect on the efficiency as you transport more cargo with the same power. This is a welcome result for ship operators, like MSC, who are watching emissions per TEU as they strive to reduce their carbon footprint."

Nevertheless, MSC voluntarily requested verification that the elongated vessel design falls below the EEDI reference line. Ihms continues: "The calculation methodology DNV GL employs for this verification has been steadily refined to the extent that today the computed result tallies almost perfectly with empirical measurements obtained in towing tank tests."

Another environmental consideration concerns ballast water management. The newly mandatory systems must have sufficient capacity to accommodate the additional volume of water the lengthened vessel needs for a ballast voyage. Anchor equipment too may need modification. Typically for non-major conversions, additional vessel weight can be accommodated by inserting extra links into the chain, rather than replacing the anchor itself.

### Capacity boost

At the same time as lengthening the vessels, MSC took the opportunity to make other changes to boost container capacity. Most notable was a decision to add more tiers above the hatch cover. Doing so entailed raising the vessels' deckhouse to ensure visibility from the bridge and adjusting the height of the funnel to prevent soot from contaminating cargo.

MSC's head of newbuilds and conversions, Giuseppe Gargiulo, told CONTAINER UPDATE: "To extract the maximum benefit from the additional tiers, we modified the lashing system and reinforced the hatch covers to cope with extra stack loads. In addition we elevated the lashing bridge by one tier."

The conceptual and structural design as well as the layout of machinery and equipment for MSC's vessel elongations was led by Hamburg-based Ship Design and Consult (SDC). With some 20 years' experience, the naval architectural office has an established reputation for designing highly complex cargo ships. More recently it has diversified by applying its expertise to vessels in service. In either case, SDC is aided in its pursuit of optimizing vessel life cycle costs by close links with HSVA, Hamburg's renowned ship model basin and the design office's main shareholder, employing its insights on propulsion efficiency and seakeeping performance.

MSC approached SDC with their initial ideas for the elongation project in autumn last year. "We were tasked with providing a proof of concept and developing them to a point where we could pass plans to the shipyards for work to begin," explains SDC Managing Director Michael Wächter. He adds that DNV GL was a key technical partner in that journey: "They provided the results of their detailed finite element calculations and granted class approval in a very short time frame. This was essential for the project to stay on schedule." SDC will continue working with MSC until the vessels complete their second delivery.

Ihms says the close partnership between MSC, SDC and DNV GL achieved in this project was critical to completing the preparatory steps needed before steel can be cut. "The structural strength and other analyses led by DNV GL revealed no unexpected obstacles and confirmed the longer vessels will meet the relevant regulatory requirements. But more importantly they provided the foundation for SDC to come up with design solutions to implement the additional innovations and optimizations proposed by MSC." ■ KT



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# GOING NORTH

Eimskip and Royal Arctic Line are leading the way to expand trade channels between Iceland, Greenland, North America, Scandinavia and the rest of Europe. The potential is huge, but conditions are challenging. DNV GL is on hand to ensure their new container vessels are fully Polar Code-compliant.

Eimskip and Royal Arctic Line have ambitious plans for the Far North. Eimskip, an Icelandic transportation specialist with a fleet of 22 vessels, and Royal Arctic Line, which has the sole concession for sea cargo transport to and from Greenland, have signed an agreement for three new container ships to boost trade between their nations and key markets to new and prosperous levels.

Diminishing regional ice coverage, married to expanding island infrastructure, has created a platform for opportunity. However, the Arctic's unique conditions require special consideration, with a need for all new ships operating in the area to comply with the IMO's recently adopted Polar Code. DNV GL is ensuring this is the case, working closely with the owners, Guangzhou Wenchong Shipyard and the designer to certify these regionally vital new ships.

## Transforming trade

Eimskip and Royal Arctic Line, which is owned by the Government of Greenland, initially signed the capacity-sharing contract in 2016. The move is being seen as, in the words of Verner Hammeken, CEO of Royal Arctic Line, "an important step for connecting Greenland to global markets."

Gylfi Sigfússon, President and CEO of Eimskip, illustrates how the vessels will help fast-track developing regional economies: "The port developments in Nuuk (Greenland), Reykjavík and Tórshavn (Faroe Islands) will enable larger vessels to serve in our market area. We assume that the cooperation will increase business activities in the Arctic region, especially between Iceland and Greenland. Activities have, until now, been limited due to lack of frequency and direct services."

Injecting the added capacity will not only transform the trade routes, but, according to Hammeken, will produce huge knock-on effects for businesses in Greenland. He states: "It creates opportunities for our export customers, allowing goods to be further refined in Greenland before transporting them directly to destinations all over the world in a more efficient way. Customers can also select transportation directly from new market areas instead of having to go only through Denmark. With this, we are looking at a future with more options, and higher efficiency, making it easy to do business with Greenland."



Connecting Greenland to the global markets: The new container ships will be delivered in 2019.

## Rigorous requirements

Doing business may be easy, but the conditions the ships encounter certainly won't be. To ensure the requisite levels of safety and environmental protection, the IMO has responded to increased levels of Arctic and Antarctic shipping activity with the new Polar Code. From 1 January 2017 all new vessels operating above 60 degrees north (extending down to a demarcated area at 58 degrees north) and below 60 degrees south must comply with the code. Vessels constructed before this date must be compliant by the first intermediate or renewal survey after 1 January 2018.

This means stringent requirements relating to vessel design, construction and equipment, with further operational needs for, amongst other things, crew training, and search and rescue capability. In the very harshest of environments, every element



The ice-classed vessel *Magne Viking* is the first vessel under new Polar Code.



of every vessel must be fit for purpose. This is where class plays a vital role.

### Expert partners

DNV GL supports shipowners in their ambitions to achieve compliant operations in polar regions - providing advisory services to help prepare for compliance and statutory certification on behalf of flag administrations.

In February 2016, DNV GL made history by certifying the first ever Polar Code-compliant vessel, working with the Danish Maritime Authority to certify the AHTS Magne Viking, owned by Viking Supply Ships. This established expertise is now in demand worldwide, much to the advantage of owners such as Eimskip and Royal Arctic Line. DNV GL China is working alongside them and China Shipbuilding Trading Company and Guangzhou Wenchong Shipyard to oversee the construction of the three 180-metre long, 31-metre-wide vessels, all of which boast capacities of 2,150 TEU. The Ice Class ships, two of which will be owned by Eimskip and one by Royal Arctic Line, are expected to be delivered in April, May and June 2019.

Deltamarin was responsible for the design of the vessels, which it notes are "designed to achieve the best possible key performance indicators, such as container carriage variety, homogeneous loading capacity, optimal manoeuvrability and harsh-weather seakeeping performance."

"We are very proud of this new contract, which further confirms our expertise in cargo ships," comments Markku Miinala, Director,

### FACTS AND FIGURES

#### Main particulars:

- Length: 179.40 metres
- Length between perpendiculars: 176.20 metres
- Width: 30.95 metres
- Depth: 17.40 metres
- Draught: 9.00 metres
- Scantling draught: 10.30 metres
- Class notation: DNV GL +1A Container Ship BWM(T), DG, BIS, TMON, LCS, ICE(1A), E0, NAUT(AW)

#### Main equipment:

- One main engine: MAN 7G60-C9.5 with EGR bypass IMO Tier III
  - MCR: 18,760 kW at 97 rpm
  - SMCR: 17,000 kW at 97 rpm

- NCR: 13,400 kW at 89 rpm including PTO power
- Three auxiliary engines: MAN 9L21/31 with SCR IMO Tier III
  - 1,980 kW × 900 rpm × C450V × 60 Hz × 3 Ph
- One auxiliary engine: MAN 6L21/31 with SCR IMO Tier III
  - 1,320 kW × 900 rpm × AC450V × 60 Hz × 3 Ph
- Scrubber system dealing with exhaust gas from one main engine and four auxiliary engines meets SO<sub>x</sub> Tier III
- Initial delivery plan: 1st vessel in April 2019, 2nd vessel in May 2019, 3rd vessel in June 2019

Sales and Marketing at Deltamarin. "The design is based on Deltamarin's extensive development work for a new generation of energy-efficient and operationally optimized 1,000-3,000 TEU container vessels intended for feeder service."

### Supporting advantage

Once operational, Eimskip and Royal Arctic Line's new assets can call on the support and service of DNV GL's regional network of bases, including its dedicated teams situated in Tórshavn, Reykjavík and Nuuk.

The vessels have the potential to chart a new route forward for regional trade. With DNV GL's assistance, Eimskip and Royal Arctic Line will be assured that the way ahead is safe, secure and 100 per cent compliant. ■ AJ



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# TERMINAL CHALLENGES

The bigger, the more economical – the conventional logic may not always apply to container ships in Asia-to-Europe traffic. Where seaports have invested in infrastructure and logistics systems, hinterland connections are beginning to reach their capacity limits. There are two possible solutions.

In recent years the volume of goods transported by the global container fleet has nearly doubled, reaching more than 200 million TEU per year. The Far East/Europe and East/West trade, while accounting for just 25 per cent of the global trade volume, cover the longest distances and have had an impact on container ship sizes: Today’s biggest vessels can carry in excess of 21,000 TEU, and 23,000 TEU vessels are on order. There is a simple logic to this: “Concentrating of the cargo on larger vessels rather than on multiple smaller vessels comes with advantages,” says Søren Toft, Chief Operating Officer at Maersk Line.

## Fewer ships, more containers

For the terminals in the world’s biggest port cities, adjusting to the mega boxers is a major challenge. At the port of Hamburg, container ship arrivals have been cut by more than half within a decade – with the overall tonnage remaining roughly the same. “Terminals must be able to handle peak workloads, moving large numbers of containers within a short period of time,” says Jan-Olaf Probst, Director Business Development DNV GL. “Afterwards the piers often remain empty until the next mega boxers arrives.”

To increase its container handling capacity, Hamburg’s terminal operator HHLA banks on automation. The Altenwerder container terminal enjoys a global reputation of being a leading-edge facility. Other sites are following suit. Just last year HHLA, supported by DNV GL, upgraded its Burchardkai container terminal (CTB) by building a highly efficient block-type storage yard. Deploying three new, fully automated stacking cranes (ASCs) doubled the storage capacity at CTB. Modernizing the terminal also improved the Hamburg port operator’s environmental footprint. “Thanks to the electrically operated cranes, we save some two million kWh of energy – the power consumption of a village of 1,200 people,” an HHLA spokesperson said.

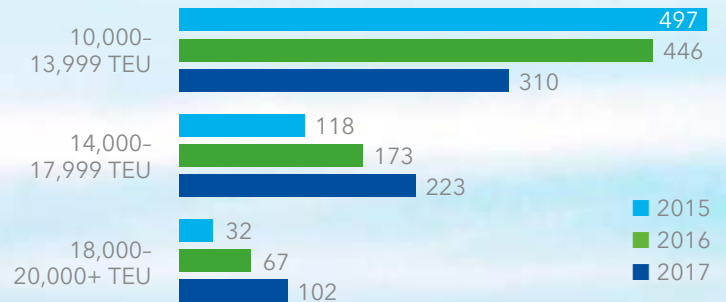
But optimizing processes at the terminal alone does not ensure a smooth flow of containers. The hinterland connections are frequently a bottleneck. “Quite a few ports are ‘Porsches’ at the front end but horse-drawn carriages at the back end,” says Probst. Outgoing road trucks often slow down the logistics flow at terminals. Traffic congestion around ports and on expressways, inadequate truck trip coordination, or customs clearance issues can cause a container waiting to be picked up to be delayed by hours or even days.

“In many ports the area needed for container storage is growing constantly,” says Probst. Another good reason for HHLA to optimize its processing management. A coordinated slot booking system implemented recently now assigns specific time windows to trucking companies. This allows containers to be distributed to road trucks faster and more efficiently during peak times.

Could using a larger number of smaller vessels help ports achieve a more continuous flow of containers at the pier and reduce traffic congestion in underdeveloped hinterland regions?

## A SHIFT IN PORT CALLS

Arrivals of container vessels more than 330 m long and/or 45 m wide at the Port of Hamburg.



Container expert Probst explains: “Unloading a 14,000 TEU ship is a much smoother process that reduces peak loads at the terminal and accelerates outbound transport to the hinterland by feeder vessel, train or road truck.”

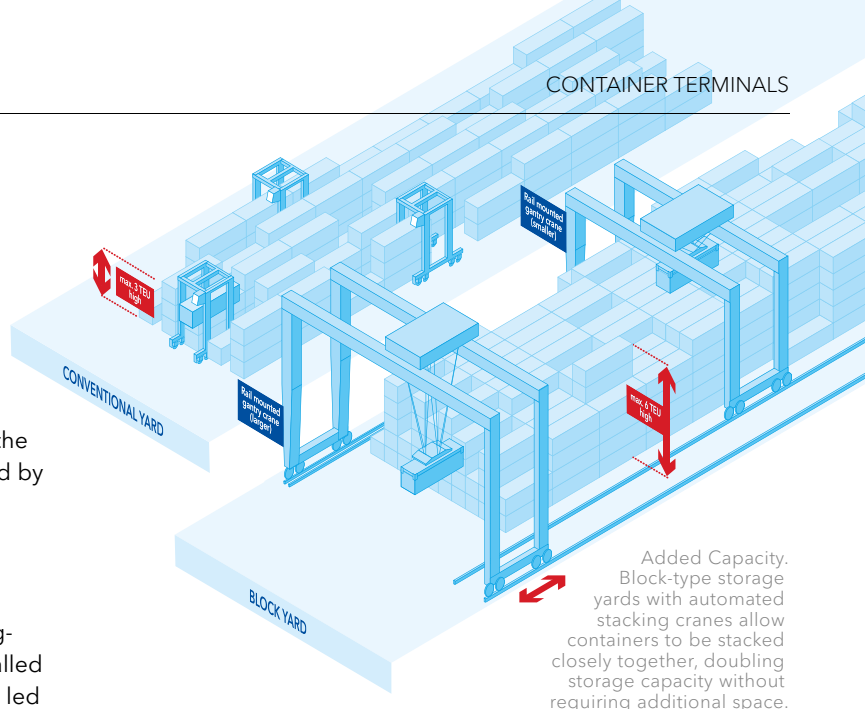
### Accelerating the transport

Bigger and more fuel-efficient ship designs were employed first in Far East/Europe service to maximize gains on that long-distance trade. Gantry cranes with longer outreach were installed in the ports along these routes to accommodate them, which led to a “cascading effect”: that smaller tonnage was pushed into the Pacific trade. The Panama Canal as well as the seaports on the US Pacific side fits to that tonnage. Additionally, the increased maximum beam of the Panama Canal to 51.25 metres will lead to a size of 14,000 TEU. Could this lead to a new around-the-world container ship design?

Smaller vessels would be more versatile and able to operate in more ports than huge, 20,000+ TEU vessels. Mega-vessels are only deployed in Asia-to-Europe trade. Before sailing to Europe, they often call at many Asian ports to collect cargo. While this trading pattern ensures high operational efficiency, “every port call delays the voyage by one day,” explains Probst. Using two 14,000 TEU boxships instead of a single 20,000 TEU vessel could reduce the number of short-sea port calls per ship, thereby accelerating the transport.

But time is not the only important factor: A well-loaded 20,000+-TEU vessel has the lowest fuel consumption per TEU. Its smaller CO<sub>2</sub> footprint contributes to IMO’s ambitious GHG reduction target. Using more, smaller ships to reduce the strain on inadequate hinterland infrastructure would increase greenhouse gas (GHG) emissions per nautical mile – not a convincing equation.

Maersk Line and MSC’s 2M Alliance as well as the Ocean Alliance formed by COSCO, CMA CGM, OOCL and Evergreen rely on 20,000+ TEU mega-boxers, whereas ONE (“Ocean Network Express”, the integration of NYK, MOL and “K” Line), Hapag Lloyd and Yang Ming, who have joined operations into The Alliance, favour 12,000 to 14,000 TEU ships. Jan Holst, Country Head Germany at ONE, explains: “Because our trading lines include many port



calls within Asia where some ports lack the required capacity, mega-vessels would be of limited use. Therefore the cyclical deployment of 14,000 TEU container ships is the right choice for us.”

Maersk Line’s current focus is to explore new approaches to unlock efficiencies in port operations in cooperation with ports and terminals, says COO Søren Toft: “A lot of value from current sized ULCSs still remains to be extracted – not least in terms of improvements in terminal productivity when accommodating ULCSs.”

While shipowners view logistics from the ship’s perspective, other members of the value chain – retailers, exporters, importers, carriers, forwarding agents, railway operators etc. – have an interest in rapid, efficient door-to-door cargo transport. Meanwhile, new start-ups such as FreightHub and Flexport are currently mixing up the industry. Online agencies and freight forwarders are driving digitalization and promoting improved transparency. Their customers can track their goods along the entire delivery chain in real time. “Eventually, increasing transparency will put more pressure on liner companies to improve efficiency,” stresses Probst. “This could become a key factor for the choice of ship sizes.” ■ GM



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Laser gun mounted near the stern inside the passageway. A target screen was placed near the bow to measure hull deflection.



# SHEDDING LIGHT ON LOADING UNCERTAINTIES

To improve safety, Seaspan and DNV GL joined forces to develop a laser measurement system as a practical means to verify loading computer data. The system, which was tested successfully on board a 10,000 TEU container ship, confirmed that the loading computer may occasionally be inaccurate.

Several moments can act on a vessel: still water bending, wave bending and whipping moments. In response to container ship accidents where the hull damage occurred in bad weather conditions, both IACS and IMO issued documents to improve design and operational safety: IACS's unified requirements for the longitudinal strength of container ships (UR S11A) focus on wave bending, the cross-sectional collapse check, and functional requirements for whipping of container ships with a beam larger than 32 metres; and IMO's update of SOLAS VI/2 addresses verification of container weights. Both documents came into force in July 2016.

UR S11A addresses the design-related wave bending and whipping behaviour, while SOLAS VI/2 pertains to the uncertainty of the still water bending moment in operation. While these requirements are necessary, they do not define detailed procedural steps. The specifics regarding whipping calculation which

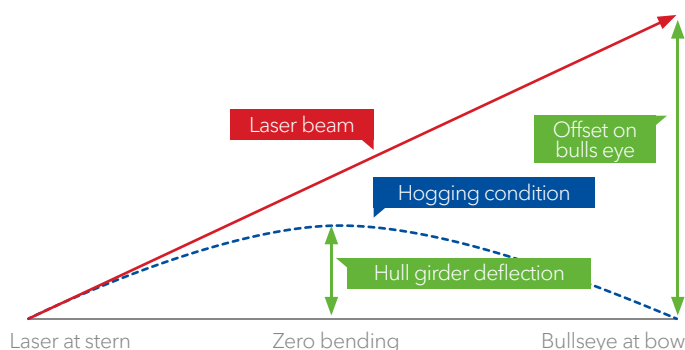
are missing from UR S11A are covered by DNV GL rules for container ships and class notation WIV. IMO and IACS do not specify requirements for wave bending and whipping in operation; this can be handled by hull monitoring associated with the DNV GL class notation HMON.

## Uncertainty lessons learned

The design specifications for a ship define a maximum permissible still water bending moment and class societies verify a permissible still water bending moment curve. During ship operation a loading computer is required to ensure that still water bending remains within defined limits. According to UR S11A there is no design-related uncertainty to still water bending. An accident investigation report on a cracked container vessel stated that there was a ten per cent uncertainty to the still water bending

**FIGURE 1: LASER SYSTEM SCHEMATIC**

Hull deflection causes laser beam to move away from bulls-eye

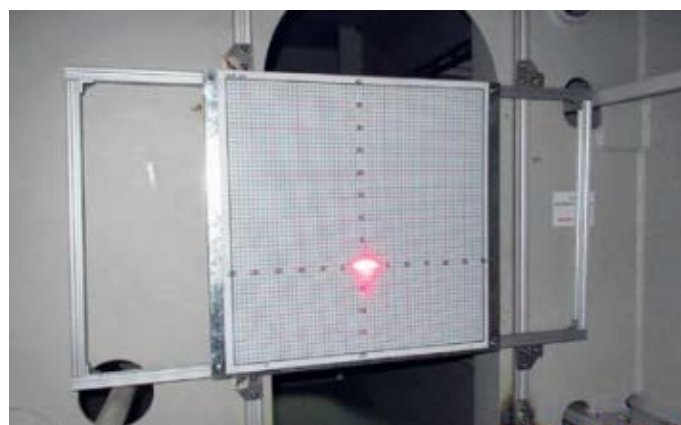


moment. If the latter was equal to the permissible maximum value, the actual hogging moment could therefore be at 110 per cent, meaning the ship was ten per cent overloaded. Seaspan and DNV GL wanted to find a solution to better handle this uncertainty.

**A simple but effective tool**

The still water bending moment is affected by several key uncertainties: Those related to container weight, which the updated SOLAS VI/2 tries to eliminate; ballast water and fuel-related uncertainties can result from manual or automatic input into the loading computer; and a third uncertainty comes into play when the loading computer calculates the balance between buoyancy distribution and mass distribution assuming a rigid hull although the hull is actually flexible. When the hull bends, the buoyancy distribution and therefore the still water bending moment change. Sea pressure acting at the ship ends also bends the ship. These two effects can be in the range of several per cent, depending on draught and ship length.

To study the deflection of the hull of a 10,000 TEU container vessel in still water conditions, Seaspan and DNV GL installed a laser gun in the stern area of the longitudinal passageway running along the top edge of the hull, and a target screen near the bow. When the hull deflects, the laser beam moves away from the bulls-eye on the target screen. The best-suited positions for the

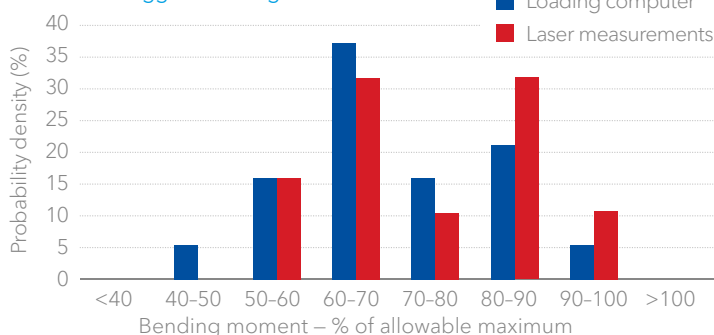


Target screen with a "bullseye" for measuring the laser beam deflection as the ship deforms under various loading conditions.

Photos: DNV GL, Seaspan

**FIGURE 2: DISTRIBUTION OF LOADING COMPUTER DATA AND LASER MEASUREMENTS**

The results suggest a fair agreement



laser gun and target as well as the conversion factor between the laser beam offset and the corresponding deflection of the hull girder were determined using finite element structural analysis. A second conversion factor was derived to estimate the still water bending moment. Calibration analysis is also essential based on the actual loading condition, preferably with the ship empty.

**First alert system for overloading condition**

Nineteen different loading conditions were assessed. For each loading condition, the loading computer data was read and a draft survey was performed. Figure 2 compares the still water bending moment distribution from the laser system with the data from the loading computer, which showed an average of 73.8 per cent of the maximum permissible bending moment, 2.5 per cent more than the loading computer, suggesting fair agreement. However, the individual differences (95 per cent confidence interval) suggest that the real hogging moment is from 15.8 per cent below to 20.8 per cent above the loading computer values, a significant residual uncertainty, while no overloading was confirmed. A significant part of this deviation is assumed to be caused by uncertainties to tankage (exact filling level and gravity).

It was further shown that using draft surveys to estimate hull bending is much less reliable than using the laser system. It is only useful for mis-declared weights, which were in the range from -1.3 to 2.9 per cent (95 per cent confidence interval) of the total declared weights. The laser system can be a good first-alert tool for potential overload situations since measurements can be taken quickly and easily in the short time between the end of cargo operations and departure. Based on the results the crew can then perform a careful check of loading computer and draught survey data. The system is being used successfully on board the vessel but for retrofits a good calibration procedure for a non-empty ship is necessary. ■ DG/GS



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