DNV·GL

CONTAINER SHIP UPDATE

2016

Ultra-large container ships

Feeder vessels

Whipping simulation

The PERFECt ship

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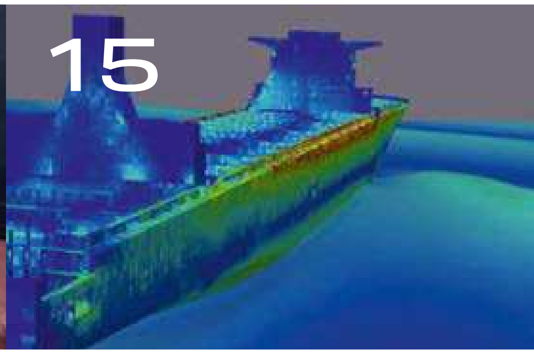

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LEADING THE WAY

The new DNV GL rules for container ships published at the beginning of this year are a major milestone achievement for us. We brought together the best of two legacies, enhancing the proven container ship standard of legacy GL with new research and innovation. The new IACS requirement UR S11A entered into force on 1 July 2016. The new DNV GL rules are fully in line with the new strength concept, having served as a model for the hull structure rules. Applying the new DNV GL rules for container ships as a comprehensive strength concept thus benefits both yards and shipowners. In addition, UR S11A requires the whipping effect to be considered in strength evaluations in accordance with the respective classification society's procedures. DNV GL has established a unique calculation method and efficient procedure for this and incorporated them in our new rules. The optional WIV notation (wave induced vibration) provides even more advanced methods for accurate prediction of the effect of wave-induced hull girder vibrations.

Does size really matter? Looking at the last decade one should think so. Hardly ever have we seen such an increase in ship sizes as with the ultra-large container ships built in recent years. In the 1970s, the focus was on big tankers, with everyone talking about the 'one million dwt tanker' – which never happened. In this issue, we look at what the next generation of ULCSs may look like and what is going on in the Suezmax arena.

Two major projects with Hyundai Mipo Dockyard are strong indicators that shipyards are trying to develop their business across all size categories as well as in higher-value-added, more specialized market segments. The Con-Green project has defined the next generation of feeder vessels. Dole continues its fleet renewal programme and recently launched three new reefer container vessels. The installation of a water cooling system on board is just one of the new measures that leads to reduced energy consumption.

In a joint development project, DNV GL and its partners have released a technical and feasibility study for a new mega-boxship – the Piston Engine Room Free Efficient Container, or PERFECt Ship. The concept ship is LNG-fuelled, powered by a combined gas and steam turbine and propelled electrically, enabling LNG operation from pier to pier without liquid fuel. The results, which are highlighted in this Update, have encouraged the project team to develop a clear outline specification in a follow-up project.

Enjoy reading!

CONTAINER SHIP UPDATE

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PUMP UP THE VOLUME

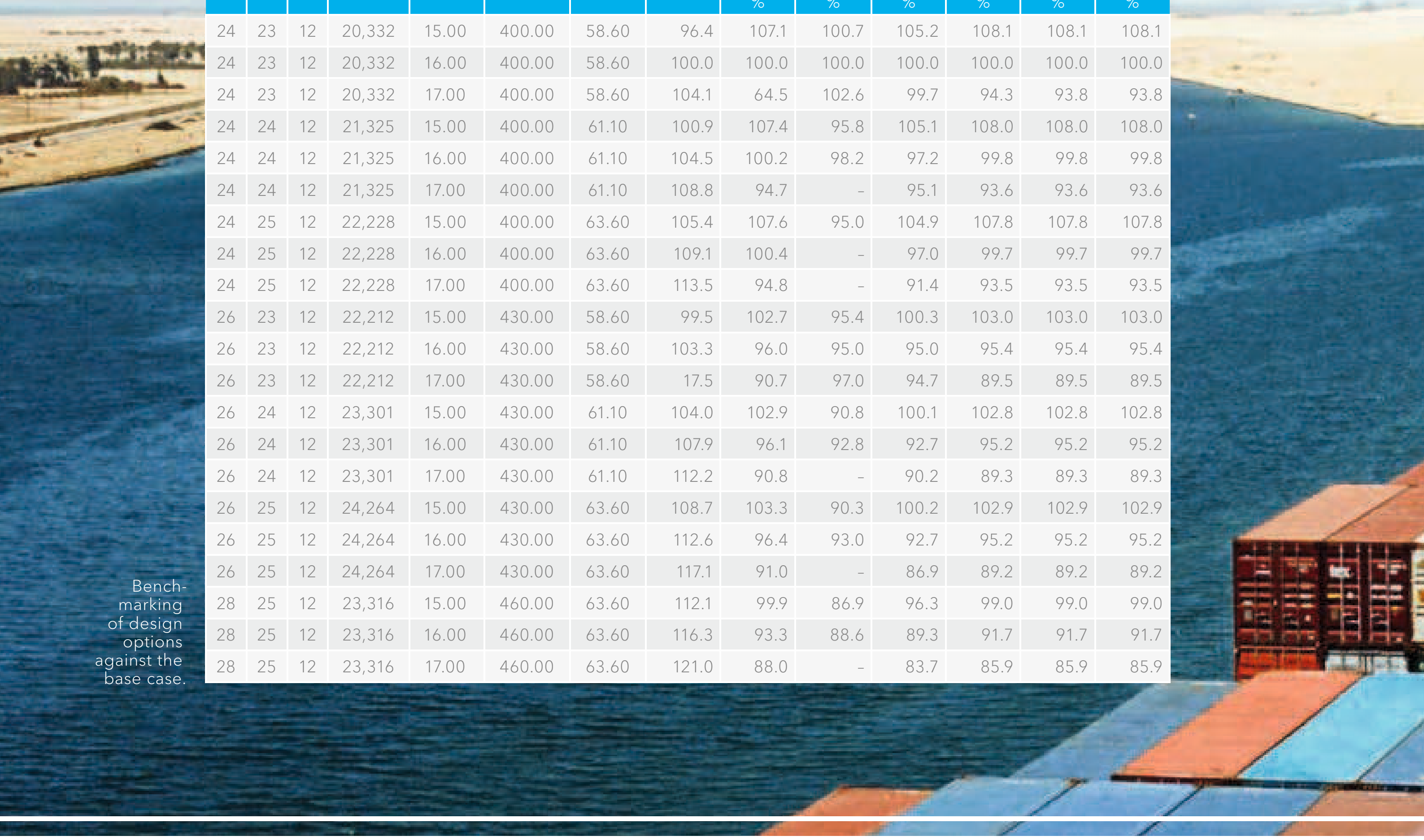
Bigger container ships are more economical, but there are limits: Major ports and canals impose restrictions on the draught, width and length of vessels, and structural stability plays an important role as well. DNV GL looks at how much further container ships could grow under these circumstances.

The trend to further lengthen and widen ultra-large container ships (ULCS) has calmed down somewhat but the interest in building bigger ships persists. A DNV GL study into the most efficient ways to increase ULCS capacity while accounting for structural robustness as well as port and waterway restrictions found that the most important limiting factor for the main particulars of next-generation ULCS is the Suez Canal.

The DNV GL study focused on two aspects: improving transport efficiency, i.e. optimizing the required propulsion power per TEU by increasing the length, beam and draught for a predefined operating profile and a range of homogeneous container weights, while accounting for infrastructural limitations imposed by seaways and ports, and the structural feasibility of such designs.

Methodical approach

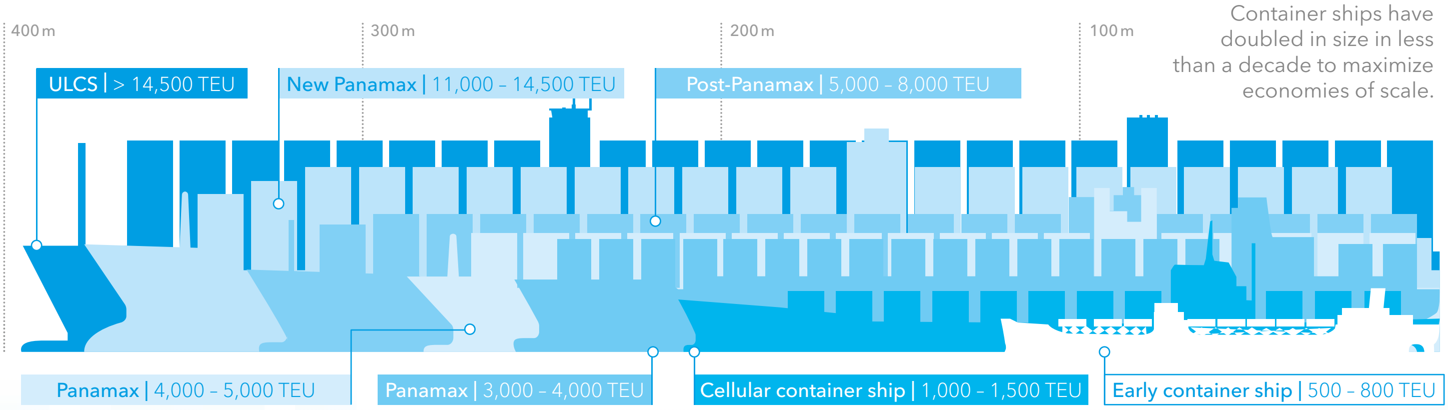
Using a proprietary methodology called “Concept Design Assessment” (see page 8), DNV GL analysed 21 variants of a possible future ULCS design, combining three different lengths (24, 26 and 28 bays, with LOA ranging from 400 to 460 metres), three beam widths (23, 24 and 25 rows / 58.6 to 63.6 metres), and three draughts (15, 16 and 17 metres). All cases assumed twelve container tiers in the hold and eleven tiers on deck, which is equivalent to a ship depth of about 33 metres.



Bays	Rows	Tiers	TEU nominal	Draught m	LOA m	Breadth m	kW %	kW/ dwt %	kW/ 8 t %	kW/ 10 t %	kW/ 12 t %	kW/ 14 t %	kW/ 16 t %
24	23	12	20,332	15.00	400.00	58.60	96.4	107.1	100.7	105.2	108.1	108.1	108.1
24	23	12	20,332	16.00	400.00	58.60	100.0	100.0	100.0	100.0	100.0	100.0	100.0
24	23	12	20,332	17.00	400.00	58.60	104.1	64.5	102.6	99.7	94.3	93.8	93.8
24	24	12	21,325	15.00	400.00	61.10	100.9	107.4	95.8	105.1	108.0	108.0	108.0
24	24	12	21,325	16.00	400.00	61.10	104.5	100.2	98.2	97.2	99.8	99.8	99.8
24	24	12	21,325	17.00	400.00	61.10	108.8	94.7	–	95.1	93.6	93.6	93.6
24	25	12	22,228	15.00	400.00	63.60	105.4	107.6	95.0	104.9	107.8	107.8	107.8
24	25	12	22,228	16.00	400.00	63.60	109.1	100.4	–	97.0	99.7	99.7	99.7
24	25	12	22,228	17.00	400.00	63.60	113.5	94.8	–	91.4	93.5	93.5	93.5
26	23	12	22,212	15.00	430.00	58.60	99.5	102.7	95.4	100.3	103.0	103.0	103.0
26	23	12	22,212	16.00	430.00	58.60	103.3	96.0	95.0	95.0	95.4	95.4	95.4
26	23	12	22,212	17.00	430.00	58.60	17.5	90.7	97.0	94.7	89.5	89.5	89.5
26	24	12	23,301	15.00	430.00	61.10	104.0	102.9	90.8	100.1	102.8	102.8	102.8
26	24	12	23,301	16.00	430.00	61.10	107.9	96.1	92.8	92.7	95.2	95.2	95.2
26	24	12	23,301	17.00	430.00	61.10	112.2	90.8	–	90.2	89.3	89.3	89.3
26	25	12	24,264	15.00	430.00	63.60	108.7	103.3	90.3	100.2	102.9	102.9	102.9
26	25	12	24,264	16.00	430.00	63.60	112.6	96.4	93.0	92.7	95.2	95.2	95.2
26	25	12	24,264	17.00	430.00	63.60	117.1	91.0	–	86.9	89.2	89.2	89.2
28	25	12	23,316	15.00	460.00	63.60	112.1	99.9	86.9	96.3	99.0	99.0	99.0
28	25	12	23,316	16.00	460.00	63.60	116.3	93.3	88.6	89.3	91.7	91.7	91.7
28	25	12	23,316	17.00	460.00	63.60	121.0	88.0	–	83.7	85.9	85.9	85.9

Benchmarking of design options against the base case.

Container ships have doubled in size in less than a decade to maximize economies of scale.



For all possible variants, the study determined the nominal container intake, the deadweight at each draught condition, the lightship weight adjusted for the results of the structural feasibility study, and the required main engine power for a speed range from 12 to 21 knots. Finally, the results were normalized and the difference in percentage was calculated for all variants in relation to the selected reference design with LOA 400 metres (24 bays), breadth 58.60 metres (23 rows), and a 16-metre draught.

The concept design assessment produced a number of findings which are of great interest to ULCS designers. The following is a summary of the changes with respect to the reference design:

- Increasing the draught improves transport efficiency of all variants for most homogeneous loading conditions. In general, a draught increase by one metre without altering the ship's length or beam results in a deadweight increase of around 20,000 dwt. It reduces the required average propulsion power per TEU by roughly six per cent for heavier container weights but is slightly unfavourable for lighter boxes.
- Widening the beam by one or two rows without changing the length improves transport efficiency as long as the

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Photo: Hearty - Fotolia

The Suez Canal is a key limiting factor for the size of future container ships.

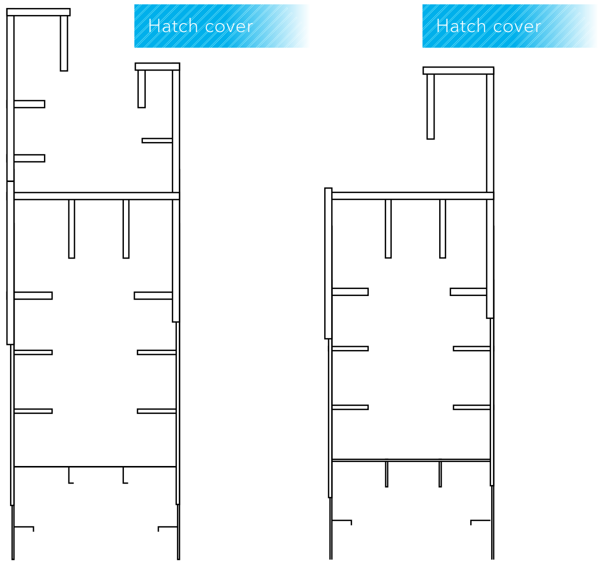

Figure 1: Upper hull girder with and without strength bulwark.

longer variants with 26 bays, considerably more steel has to be placed in the upper hull girder to meet the section modulus requirement; this increases steel weight and building costs. On the longest, 28-bay ship variant the traditional upper hull girder design was found to be unsuitable for the required steel thickness. A "strength bulwark" on top of the sheer strake has to be incorporated to satisfy the section modulus requirement, (see Figure 1).

This in turn causes an upward shift of the neutral axis of the cross section, particularly for the variant with strength bulwark, while exposing the double bottom to higher hull girder stresses. To be able to continue using steel with a yield strength of 355 N/mm² (YP355) in the bottom area, plate thicknesses had to be increased there as well. To account for additional stress components, e.g. double bottom bending, which are normally analysed at later stages of the design process using FEM-based methods, the section modulus at the outer bottom was dimensioned with a minimum margin of 13 per cent for all variants. Using high-yield steel in parts of the midship area reduces weight but might pose other

> homogeneous container weight remains low.

- Adding one hold (two bays) to the length of a ship with a 23-row beam improves transport efficiency by about five per cent for all loading conditions. Widening the beam additionally increases the capacity but does not improve transport efficiency.
- A vessel lengthened by two holds (totalling 28 bays lengthwise) and widened to 25 rows will offer a transport efficiency improvement of roughly eight to eleven per cent, depending on the average weight of the containers.

Port restrictions are another important consideration. While rarely an issue in Asia, draught, length and width restrictions have been imposed by many European ports, usually because they are located in tidal waters or many miles up a river. Several ports in northern Europe permit ship lengths up to 400 metres only, and in some cases impose limits on the beam and draught as well. Length restrictions might be relaxed in future to accommodate ULCS up to 430 metres long, provided the vessels are specifically equipped for efficient manoeuvring. Nevertheless, with ULCS dimensions continuing to increase, some European ports will no longer be able to serve as final loading or first discharge ports.

A key limiting factor for global container shipping is the Suez Canal, which currently allows passage for ships with a 59-metre beam and a 17-metre draught.

Structural feasibility study

The structural analysis performed by DNV GL on all design variants focused on the midship section, assuming a maximum plate thickness of 90 mm and a steel yield strength of 460 N/mm² (YP460) in the deck area, and 355 N/mm² (YP355) in the bottom area. Because of certain mechanical relationships between bending moments and ship dimensions, adding one bay lengthwise has a much greater effect on steel weight than adding a row. This means that for the

Efforts to further boost the capacity of ultra-large container ships require careful consideration of many parameters to achieve true economic benefits.

Photo: ptnphotof – Fotolia

challenges which require further investigation. The study also found that increasing the scantling draught from today's 16 metres to 17 metres would not have a significant effect on structural properties.

The study shows that next-generation ULCS can be designed and built without requiring major changes to current design concepts or structural arrangements. The most likely approach to enlarging the reference vessel would be to increase the beam to 24 rows to expand the nominal capacity by roughly 1,000 TEU, achieving a nominal capacity of around 21,500 TEU (refer to table). The fuel costs per TEU will remain nearly the same. Increasing the maximal draught of such a 24-row ULCS from 16 to 17 metres will boost the deadweight capacity by about ten per cent and improve fuel efficiency.

An even higher nominal capacity could be achieved by lengthening the vessel by one cargo hold, or two bays, to raise the intake to approximately 23,300 TEU, thereby reducing the fuel costs per TEU by 4.5 per cent. These modifications could be implemented in today's operating environment without facing restrictions from current port and seaway infrastructure.

What next?

In theory it would even be possible to design a vessel 25 rows wide and 26 bays long with a 26,300 TEU capacity. However, such a ULCS would be unable to enter several major ports or pass through the current Suez Canal when fully loaded. It would also require a new structural design concept involving "strength bulwark" on top of the sheer strake. This makes it appear unlikely that such a vessel will be ordered any time soon, in spite of the promise of an additional 3.5 per cent reduction in fuel costs per TEU. **AK**

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AN EXTRA MARGIN OF SAFETY

To improve the safety of container transport, a new SOLAS regulation now requires the gross weight of packed containers to be verified. DNV GL explains the implications.

The art of stowing and stacking containers on board ships to ensure cargo and ship stability – and ultimately, the safety of people and property – depends on the availability of accurate information on the weight of each container including its contents. While shippers have been required to specify the gross weight of every container under the International Convention for the Safety of Life at Sea (SOLAS) for a long time, there have been enough errors and inaccuracies in the past to warrant the introduction of an additional margin of safety. The amendment to SOLAS regulation VI/2 requiring evidence of the verified gross mass of packed containers as defined in IMO Circular No. 3624, dated 10 February 2016, came into force on 1 July 2016.

In essence, the verified gross mass (VGM) amendment says that the gross weight has to be determined by using "calibrated and certified equipment"; as an alternative, the gross weight could be calculated by weighing every item loaded, including the packaging material, and adding the container tare weight to the sum of the contents. The weighing method needs to be certified by the authorities of the country in which the container is packed.

The new VGM requirements apply to containers on any vessel subject to SOLAS Chapter VI except containers on chassis or trailers carried on board a ro-ro ship on a short voyage, and offshore containers not subject to the International Convention for Safe Containers (CSC).

Shared responsibility

It is the shipper's responsibility to verify and document the gross mass of each container, sign the declaration, and transmit it to the shipping company and the terminal representative before the ship stowage plan is prepared. The shipmaster is responsible for ensuring that only containers accompanied by shipping documents reflecting the required VGM documentation are on board. Since the VGM amendment does not specify a time limit for submitting the verified gross weight information, the shipping company must set a deadline for the shipper to deliver this documentation.

The shipping company must refuse to load any container lacking a VGM or exceeding the permitted gross mass as defined by the CSC. Any resulting costs are a matter of the contractual agreements between the shipper and the shipping company. Enforcement for the SOLAS amendment is the responsibility of the respective SOLAS signatory country, and non-compliance is subject to national legislation and jurisdiction.

The IMO has set a three-month grace period ending 1 October 2016 for containers loaded before 1 July 2016 and transshipped on or after 1 July 2016 to their final port as defined in MSC.1/Circ. 1548. Furthermore, IMO recommends to accept room for improvement towards the full implementation.

What DNV GL recommends

Any problems or challenges encountered should be openly discussed between the shipping companies and the shippers, port facilities and flag states to establish a common approach as far as practical.

It is advisable to review operational procedures and, where applicable, include VGM topics such as a deadline for submitting VGM information, use of VGM data in loading software, the desired transmission channel for VGM information, and the handling of containers with an overdue or missing VGM declaration. DNV GL is happy to assist customers with any questions pertaining to the implementation of the VGM amendment. Ships carrying containers are advised to have a copy of the MCS.1/Circ. 1475 and MSC.1/Circ. 1548 on board in case of an inspection by the Port State Control Officer or other administrative body and to consult the local requirements defined by IMO. ▮ CO

Photo: DNV GL

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OPTIMIZING CONCEPT DESIGNS

In times of slow steaming and partial loading conditions, optimizing ship hulls for one draught and speed only is no longer feasible, especially for container vessels. New concept design criteria have been adopted by the industry.

Ship design experts are generally in agreement today that ships should be optimized along a specified speed and draught range ("operational profile"), and owners of large container ships consistently follow this approach. Nevertheless, concept design frequently focuses exclusively on hydrodynamic considerations, neglecting the interaction with deadweight or stability issues. This approach aims to minimize fuel consumption (the cost side) while keeping the deadweight and stability unchanged (the money-earning side). Attempts have even been made to cut fuel consumption further by reducing the deadweight and/or sacrificing stability.

The question remains whether this approach will automatically result in the most economical design. DNV GL Maritime Advisory strongly believes it is time to take a broader view at the optimization process by not only minimizing total fuel consumption but also fuel consumption per cargo ton transported by a specific container vessel so as to minimize fuel consumption per container. >

Photo: shaunl - iStockphoto

Extending ship concept design beyond mere hydrodynamics harbours additional savings potential.

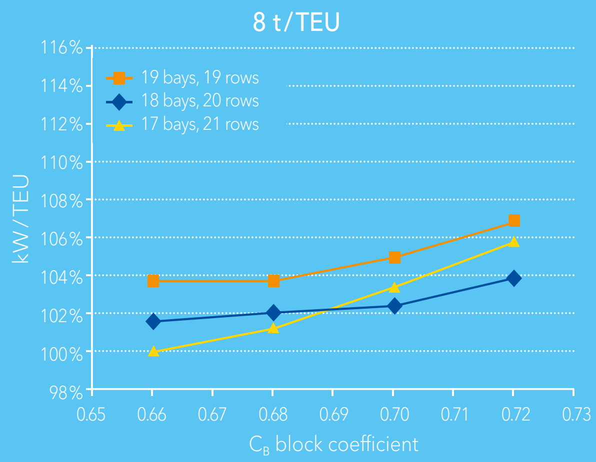
> Concept Design Assessment (CDA) is a new DNV GL service based on a proprietary methodology to optimize the initial specifications when a new design is developed. The purpose is to find the most favourable main dimensions to minimize the costs per transported container for a given operational profile and specific cargo mix.

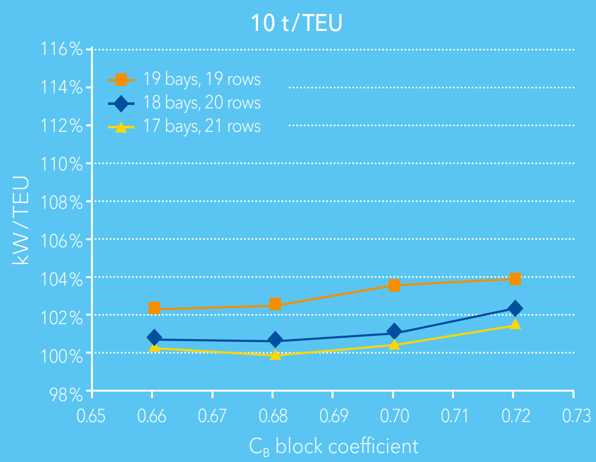
The experts at work

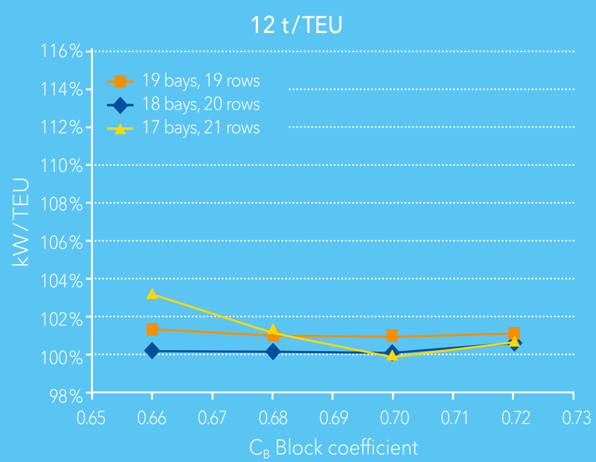
The process typically begins by specifying a number of length/breadth variations and a range of block coefficients (C_B) to be investigated. DNV GL experts will then perform iterative calculations on the selected main dimensions and block coefficients, estimate the lightship weight and centre of gravity, predict speed vs power curves for the operational profile, and assess the stability and maximum number of loadable containers for a range of container weights (8 t/TEU to 16 t/TEU). In the next step, the average power demand for the specified operational profile is computed, followed by the average number of loadable containers for a specified cargo mix. The combination of main dimensions and block coefficients featuring the lowest power demand in kW/TEU for the specified operational profile and cargo mix will then be selected.

Most of the process is scalable. For a rough estimate, all parameters needed for the assessment can be derived from empirical formulas. For a more sophisticated look at the interdependencies, a hull shape can be derived from a parent hull form, allowing the container slots to be counted and predictions on the power requirement to be made using computational fluid dynamics (CFD) rather than empirical methods. The intact and damage stability can be calculated directly using a simplified geometry model of the hull, holds, rooms and tanks instead of GM limit curves from similar ships. Preliminary midship sections can be designed for each variant and used for a more accurate estimate of the steel and lightship weight than what would be possible using empirical formulas. For the most promising concepts, a formal optimization process for the hull shape can also be included in the scope of work.

The CDA service has already been put to good use in several commercial projects, helping shipping companies choose the most advantageous main dimensions for their newbuilding projects. In addition, DNV GL undertook an internal study for an 11k/12k TEU container ship development project (refer to infobox). **UH**







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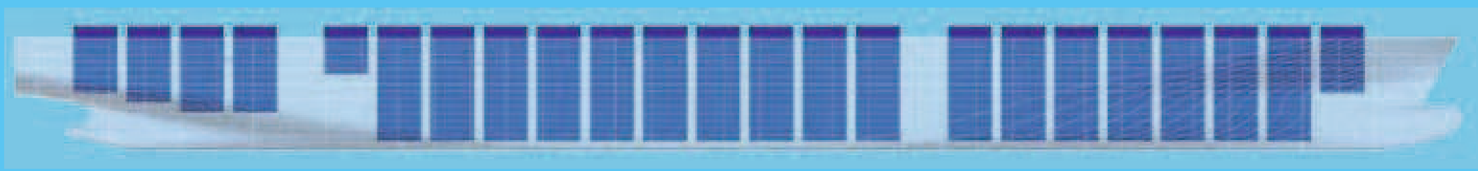
THE 11K/12K TEU CONTAINER SHIP PROJECT



Concept design examples – lateral view (above) and 3D view (below) of computer-generated models

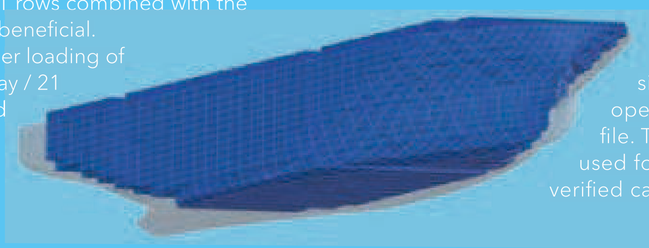
The following variants were investigated for the 11k/12k container ships:

- Length/breadth combinations: "19 bays, 19 rows", "18 bays, 20 rows" and "17 bays, 21 rows"
- Block coefficient variants: C_B 0.66, 0.68, 0.70 and 0.72

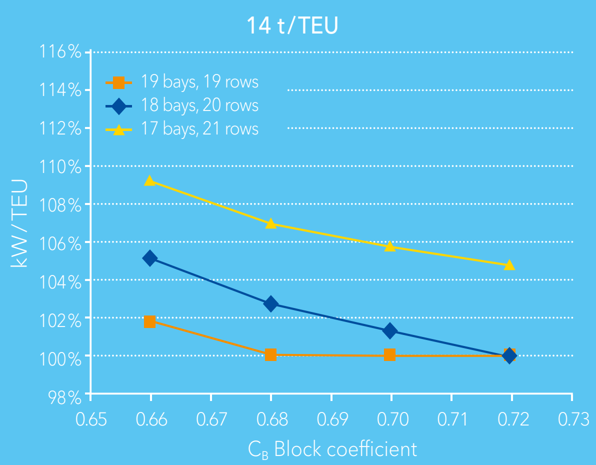
The average power demand per container was determined for an assumed speed profile, and corresponding plots show the effect of the average container weight and the block coefficient on the performance of the respective design concept.

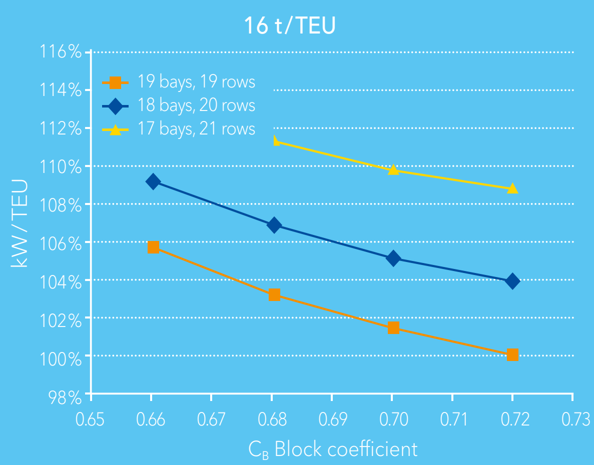
Conclusions for the 11k/12k container vessel project:

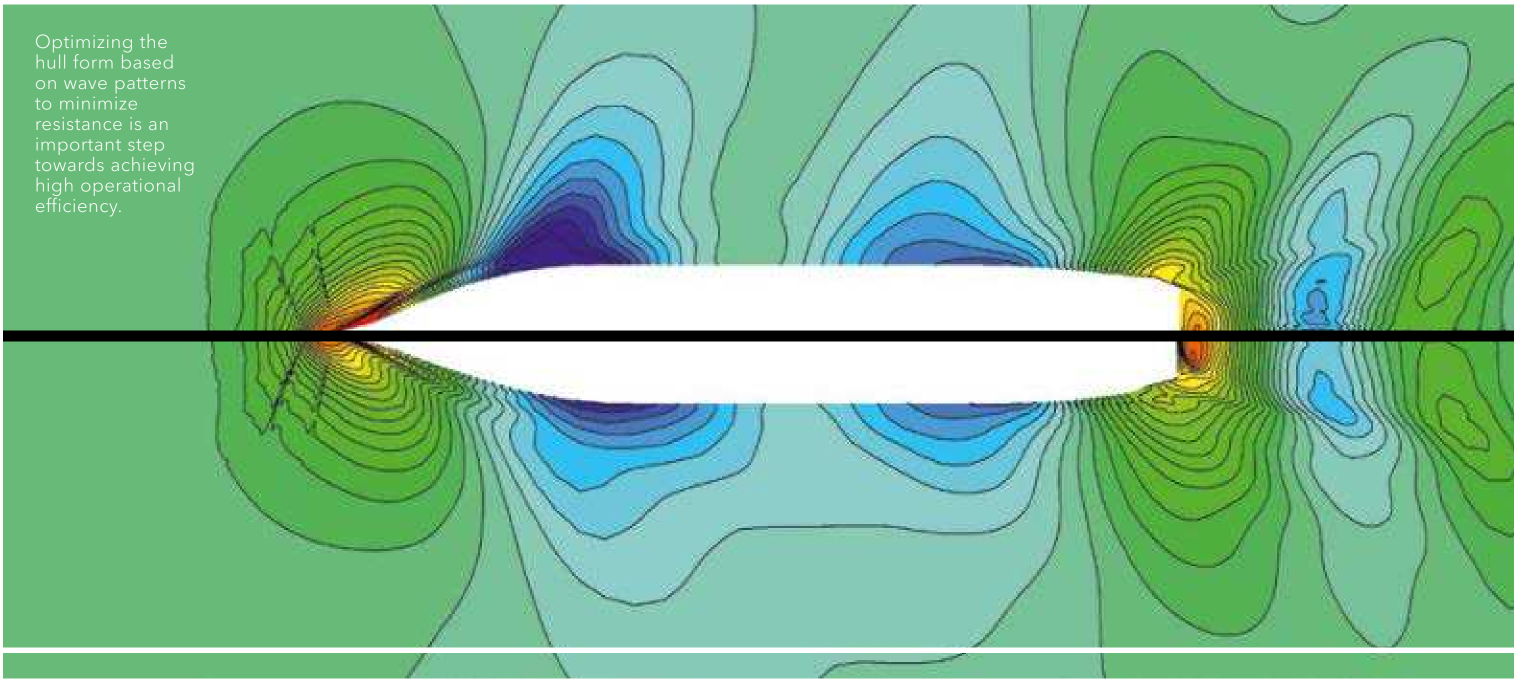
- For a homogenous container loading of 8 t/TEU, the short and beamy concept with 17 bays and 21 rows combined with the lowest block coefficient C_B=0.66 is beneficial.
- Similarly, for a homogenous container loading of 10 t/TEU, the short and beamy 17 bay / 21 row concept is likewise the preferred concept, closely followed by the 18 bay / 20 row combination. The optimal block coefficient is C_B=0.68.
- For a homogenous container loading of 12 t/TEU, the three length/breadth concepts achieve nearly the same performance, with the 18 bay / 20 row variant at a slight advantage. The block coefficient should be in the C_B=0.68…0.70 range.
- For a homogenous container loading of 14 t/TEU, the long and narrow concept with 19 bays and 19 rows is preferable. The block coefficient should be in the C_B=0.68…0.70 range or slightly above. This is what is typically designed and built today.
- For a homogenous container loading of 16 t/TEU, the long and narrow concept with 19 bays and 19 rows is likewise preferable. The highest beneficial block coefficient investigated here is C_B=0.72.



Note: The optimal main dimensions depend heavily on the size of the ship and its expected operational draught and speed profile. The above findings should not be used for other projects without being verified carefully.







Optimizing the hull form based on wave patterns to minimize resistance is an important step towards achieving high operational efficiency.

CON-GREEN 2000 – THE BANGKOK-MAX

The largest container vessels are designed for the greatest possible efficiency – maximum intake, minimum fuel consumption. Their smaller cousins, however, have not received the same level of attention – but this is beginning to change.

For the last few years, the titans of the container world have stolen the headlines; 18,000, 19,000 and even 20,000 TEU giants have arrived and reshaped the way goods are transported around the world. This has resulted in a need for more feeder services to keep these giants filled and reap the efficiency benefits of their size.

For the Korean shipbuilder Hyundai Mipo Dockyard (HMD) this was a good reason to look into the designs of feeder vessels and identify energy savings potential for this ship type as well. "With the Con-Green 2000 project we wanted to define the next generation of feeder vessels with maximum fuel efficiency, high quality, reliability and lower maintenance costs," says C. G. Lim, Team Leader and Deputy General Manager of the ECO Hull Form Development Team at HMD. The yard asked several partners to participate in the project, including MAN Diesel & Turbo, Becker Marine Systems, and DNV GL.

The hull form, propeller, general arrangement, midship section and scantling have been designed and optimized by HMD using their own proprietary software Hull Form Optimizer of Mipo (HOM) and Propeller Optimizer of Mipo (POM). The hull design of this Bangkok-max vessel was based on the new DNV GL rule set and the new IACS S11A and S34 requirements, and given approval in principle by DNV GL.

Efforts to optimize the hull and propeller have led to power savings of approximately 7.5 per cent. Cargo capacity was maximized by minimizing the weight of the vessel and optimizing the structural arrangements. A further capacity increase could be achieved through a tailored Intra Asian Service loading plan under the DNV GL RSCS (Route Specific Container Stowage) class notation, allowing the deck containers' VCG (vertical centre of gravity) to be raised by 13.5 per cent compared to the standard North Atlantic route. As a result of optimizing the loading condition and LCB position (longitudinal center of buoyancy), the fore and aft peak tanks were removed.

Innovative rudder design

"Reducing fuel consumption is the most effective way to improve the emissions profile of a vessel, while, at the same time, improving competitiveness. The design includes a Cross Over Rudder (COR) developed by Becker Marine Systems (BMS), which will provide efficiency benefits over a wide range of loading conditions, speeds and real sea conditions with waves, winds and current," says Lim.

The COR is a new design from BMS that includes a new fairing hub cap and a new rudder bulb design. The flow efficient hub cap

(FEHC) and the rudder bulb are designed to reduce the required power and prevent propeller hub cavitation with no loss of manoeuvrability. The addition of the COR reduced the power requirement by another 2.8 per cent.

"BMS has a long history of cooperation with HMD and we were very pleased to have been asked to take part in this interesting project, " says Henning Steffen, Naval Architect and Sales Manager from BMS. "We took the data provided by HMD and undertook CFD calculations to find the ideal COR rudder design for maximum efficiency. After seeing the model testing results, we are especially pleased with the power savings added by the COR over the whole range of operational speeds."

Model tests confirm better performance

The design also incorporates the latest version of the MAN B&W 6S60ME-C10.5 main engine from MAN Diesel & Turbo (MDT). "At MDT, we are always interested in projects which can contribute to the development of innovative designs that benefit builders, owners and operators," says Sang Bae Cha, Sales Promotion, MAN Diesel & Turbo Korea. "The Con-Green project was an excellent opportunity to feature the new MAN B&W 6S60ME-C10.5, which has increased power, improved fuel efficiency and reduced weight and dimensions, and also features new technologies like our fuel booster injection valve and top-controlled exhaust valve." Model tests carried out in June at Force Technology in Denmark and witnessed by a DNV GL expert confirmed the added performance, with the speed at NCR (nominal continuous rating) power with 15 per cent sea margin improved by about 0.55 knots in comparison to the original design. Daily fuel oil consumption was improved by 12 to 16 per cent, depending on the vessel speed.

DNV GL will work with HMD on obtaining an approval in principle for the design, verify the performance of the design and assess the compliance of the design with environmental requirements including the EEDI. DNV GL will also provide technical support on the basic design in terms of stability, cargo loading/unloading, and the machinery arrangement concept and placement.

"The feeder market is gaining in importance, especially in the intra-Asian sector, and we are seeing a wave of innovation in this area as yards and designers look to maximize efficiency and reduce environmental impacts," says Jai Oh Sun, responsible engineer for the Con-Green project at DNV GL – Maritime. "We are very pleased that HMD has chosen us to participate in the project and trusts our expertise in the container sector. We look forward to the future development of the design and its success in the market."

HMD Con-Green 2500 and HMD Con-Green 3000 are now under development and will be released soon. ▮ SA

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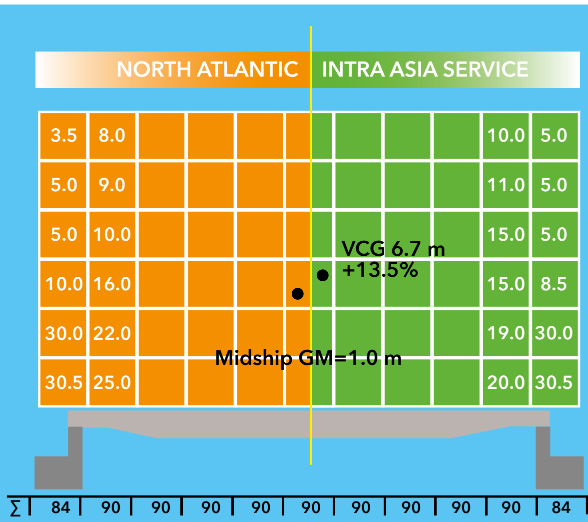
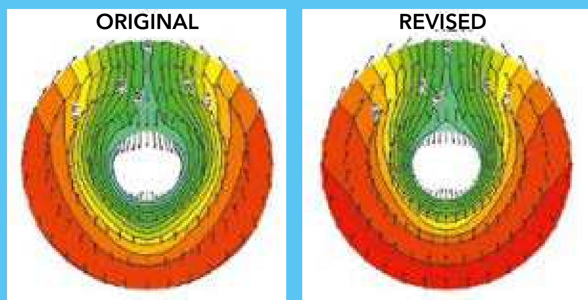


Route-specific stowage allows for a higher vertical centre of gravity (VCG) and more advantageous loading.

The Cross Over Rudder by Becker Marine Systems reduces power requirements, contributing to ship efficiency over a wide range of operating conditions.



Wake distribution: Hull and rudder optimization improves the wake pattern, an indicator of the efficient use of power.

Comparison of main particulars	Original design (ORI)	Revised design (REV)
Length between perpendiculars	163.0 m	163.55 m
Beam	27.5 m	27.4 m
Draught	8.75 m	8.75 m
Normal continuous rating	9,500 kW	8,517 kW
Sea margin	15.0%	15.0%
Service speed	19.0 kts	19.0 kts
Nominal capacity	1,785 TEU	1,801 TEU
14 tonnes homo. capacity	1,210 TEU	1,240 TEU
Energy saving device	Applied	Applied

Photos: Becker Marine Systems, DNV GL, Hyundai Mipo Dockyard

SAFETY AT A CONSISTENT LEVEL

While consideration of whipping effects is included in the new DNV GL rules, the class notation WIV supports more advanced methods and procedures for predicting the whipping behaviour of a vessel.

The International Association of Classification Societies (IACS) has revised the longitudinal strength standard for container ships (UR S11A), and added unified requirements to load cases for strength assessment of container ships (UR S34).

These requirements had been incorporated into the DNV GL rules for container ships from January 2016 on a voluntary basis, and became mandatory on 1 July 2016. One of the great benefits of the new DNV GL rules is that the UR S11A design requirements for structural assessment follow the same philosophy as the structural assessment defined in the new DNV GL rules. For Post-Panamax container ships (breadth >32.26 m), UR S11A requires the effect of extreme whipping response to be considered in the strength evaluation in accordance with the respective classification society's procedures. DNV GL has established a simplified and efficient procedure for this purpose which has been incorporated into the new rules. In addition, the DNV GL rules include whipping and springing in the wave bending moment used for fatigue assessment.

A ship-specific approach

More advanced methods are supported by the DNV GL voluntary WIV notation and class guideline on an optional basis. These methods and procedures allow a more reliable prediction of the effect of wave-induced hull girder vibrations, thereby giving increased accuracy and consistency to the applied safety factors. The procedure for obtaining the WIV notation takes a two-level approach:

- Level 1 offers assessments based on empirical factors which represent an increase in the wave-bending moment for ultimate and fatigue loading.
- Level 2 is based on further numerical analyses or model tests, which are regarded as necessary if any parameter such as the ship speed, length, beam or bow flare exceeds certain limits.

Level 1 enables a quick-and-easy estimate based on the data gained from several model tests and hull monitoring systems installed on DNV GL-classed container ships. A direct Level 2 analysis gives a refined picture of the hydrodynamic loads, including wave-induced vibration effects computed using validated and tested numerical tools. Unlike the empirical estimate, the computational approach accounts more accurately for the individual vessel's hull shape, loading patterns, and available propulsion power. The latter is essential in order to estimate the speed in any sea states. As an example the extreme whipping response does not occur in the highest sea states, but in moderate storms at high speed. **AKA/GS**

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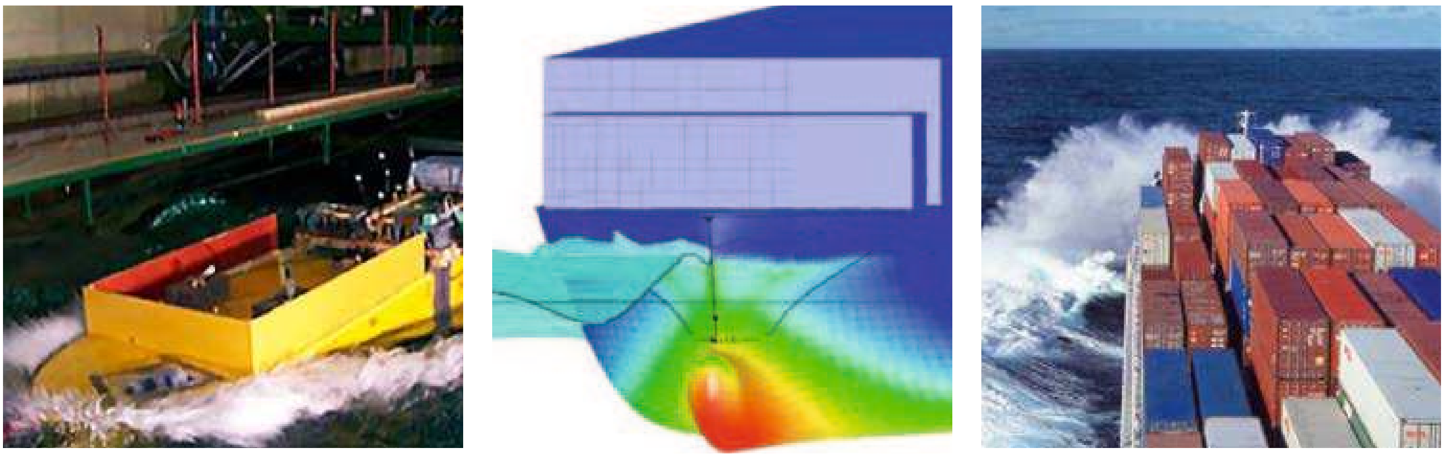


Photos: DNV GL

Towing tank testing and CFD calculations are advanced options for determining hull responses to wave-induced vibration for design. In operation hull monitoring systems (class notation HMON) ensure safety and complement the loading computer.

DNV GL uses the most accurate numerical method available to compute hydrodynamic loads.

CONTROLLING WHIPPING STRESSES

To better understand wave-induced hull vibration when assessing hull girder collapse characteristics, DNV GL has developed a computational approach that accounts for the ship's individual hull shape and propulsion power and is seamlessly embedded into the structural design process.

It is a well-known fact that hull girder vibration induced by bow slamming impacts, commonly referred to as "whipping", may considerably increase the still-water and wave-bending moments acting on the hull girders. This is most critical for hogging-type hull deflection patterns when the double bottom is exposed to high compressive stresses. When these stresses exceed the buckling capacity of some shell or double-bottom plating, this may trigger the progressive collapse of larger structures and, ultimately, of the whole hull.

Conventionally the amplification of structural stresses due to whipping is covered by implicit safety margins in the design rules. However, this has become questionable in view of the rapid development of new container ship designs. Many shipowners are concerned whether their ships are strong enough to withstand loads associated with severe and violent sea conditions. Large and ultra-large container carriers are the focus of these concerns because of their exposure to very high slamming loads.

Analytical concept

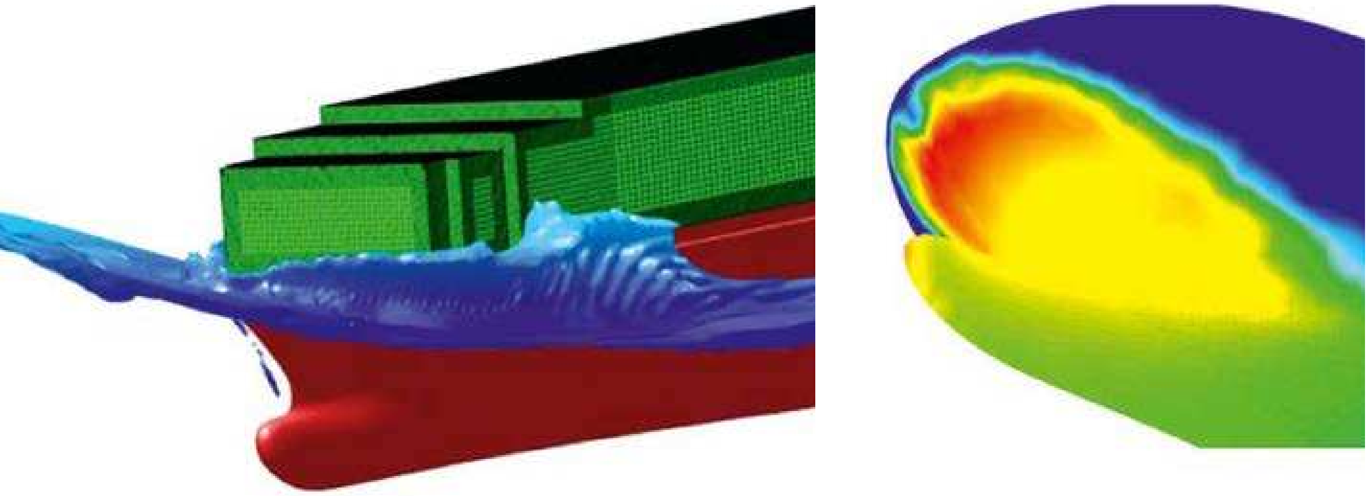
DNV GL developed its computational approach under the premise that the deadlines for submitting the final key structural drawings for plan approval and steel ordering must not be delayed by time-consuming computing. This has been accomplished by performing the computation of the extreme whipping loads and ultimate hull girder capacity in parallel with the strength analyses typical for large container vessels.

Whipping involves highly non-linear effects and thus requires the application of high-fidelity numerical methods. DNV GL uses computational fluid dynamics (CFD) based on the numerical solution of the Reynolds-averaged Navier–Stokes (RANS) equations, combined with simultaneous calculation of ship motion and deflections. The most accurate numerical method available today, this enables explicit definition of hydrodynamic loads without the need for ad-hoc models or additional safety margins.

Loads due to slamming and consecutive whipping strongly depend on the forward speed of a ship. Assuming a constant speed is unrealistic, particularly for whipping loads: it would be excessively conservative in severe sea conditions (where the ship is unable to maintain a constant speed) but not conservative enough in moderate conditions (when the ship may sail at a higher speed). The approach chosen by DNV GL accounts for involuntary speed reduction due to added resistance in waves, based on the vessel's individual hull shape and propulsion system and defined individually for each sea state.

Predicting slamming is not a trivial task

The use of CFD is already widely accepted for hull resistance predictions, and there is growing interest in its application >



CFD simulation of slamming event: free surface (left) and bow pressure distribution (right).

> for seakeeping and load analysis. The inherent supremacy of CFD for wave impact load analysis is due to the implicit account taken of strongly non-linear effects: wave breaking, splash and green water effects are directly computed and do not need ad-hoc models or empirical calibrations. DNV GL has pioneered developments in this field and has routinely used CFD for wave load predictions for more than a decade.

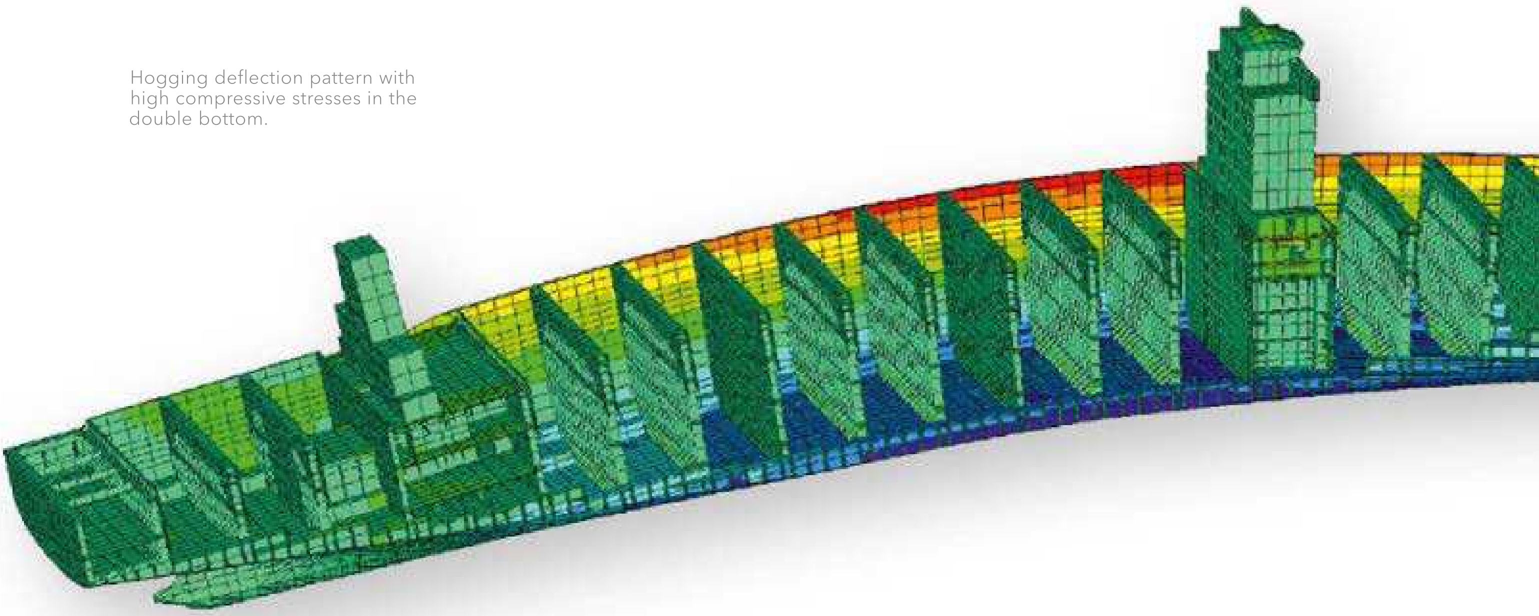
A different approach

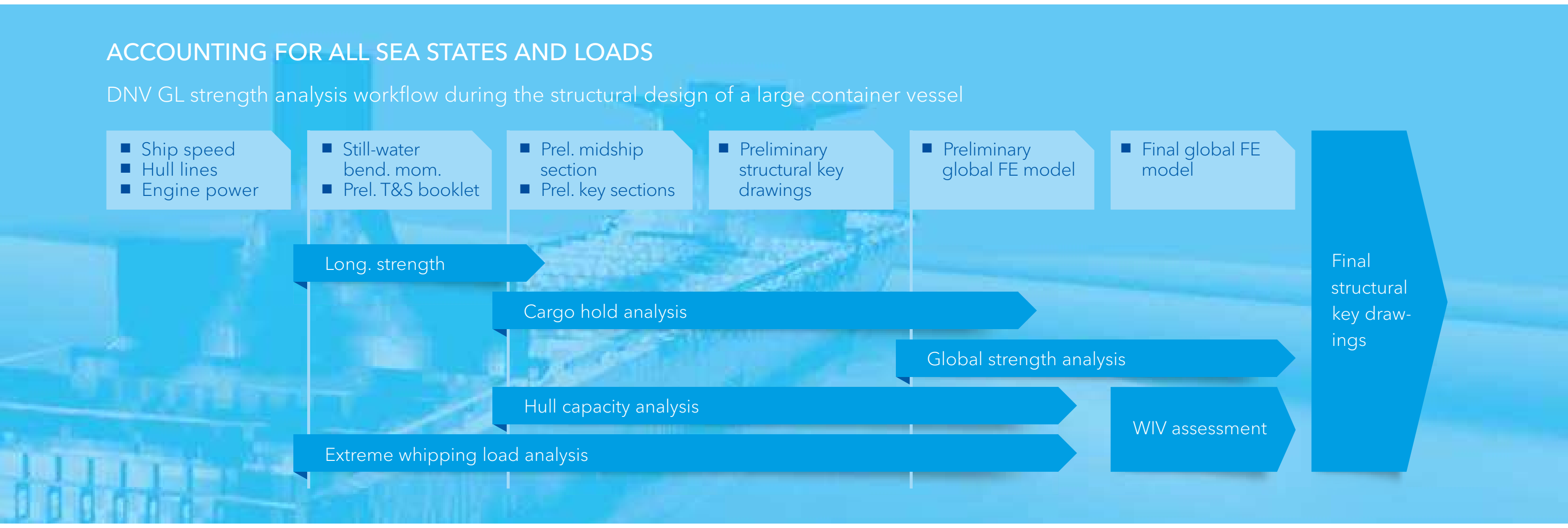
Coupling CFD solvers with ship motions and flexible deformations to incorporate the interaction of fluids and structures into the computed solution has required significant work. Many years of experience in using coupled solvers in whipping analyses and extensive validation work justify strong confidence in the results. Thanks to substantial research and practical experience, DNV GL is able to offer a unique hydrodynamic assessment procedure, combining the ship- and sea-state-specific maximum achievable ship speed, high-fidelity CFD methods and a comprehensive non-linear statistical analysis concept.

Unlike widely used simpler approaches to estimating extreme loads, the DNV GL method accounts for all sea state conditions the ship might encounter – not only extreme sea states at slow sailing speeds but also moderate seas where heavy slamming can occur at high ship speeds. This allows the whole wave scatter table to be covered so that the effect of wave-induced vibration on load amplification can be predicted accurately.

Where required, assumptions and simplifications, which are unavoidable in any theoretical analysis, are made on the safe side. The wave climate of the North Atlantic is used according to IACS Rec. 34, without including weather routing effects. The 100 per

Hogging deflection pattern with high compressive stresses in the double bottom.





cent still-water and 100 per cent wave-induced bending moments are summed up without any reduction factors, although such a combination is extremely unlikely to occur. Moreover, the analysis uses the maximum achievable speed in the seaway, i.e. voluntary speed reduction is ignored. Further assumptions concerning the wave heading distribution and the dependency of whipping loads on the wave heading are made on the conservative side. While the procedure takes a cautious approach, several commercial projects have shown that the results agree with design experience and are not overly conservative. This is important to note as any unexpected results may lead to additional design loops.

The way ahead

By statistically evaluating AIS data in combination with weather hindcast data, DNV GL confirmed that severe storms are typically avoided by shipmasters through rerouting. Such statistical observations, combined with the enhanced use of hull monitoring systems, will enable more realistic assumptions about the environmental and operational conditions a vessel will experience during its service life. This represents the basis for the continuous adaptation of the DNV GL design rules and methods to account for new technological developments. ▮ **HM**

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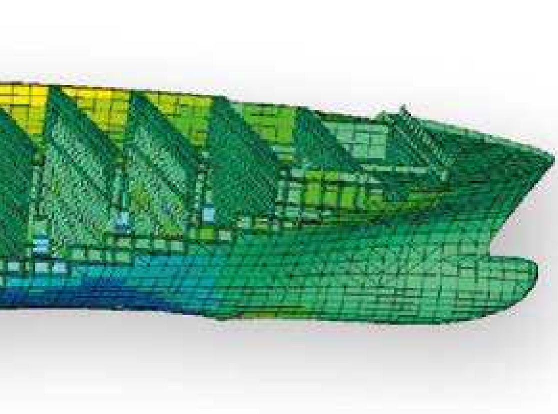

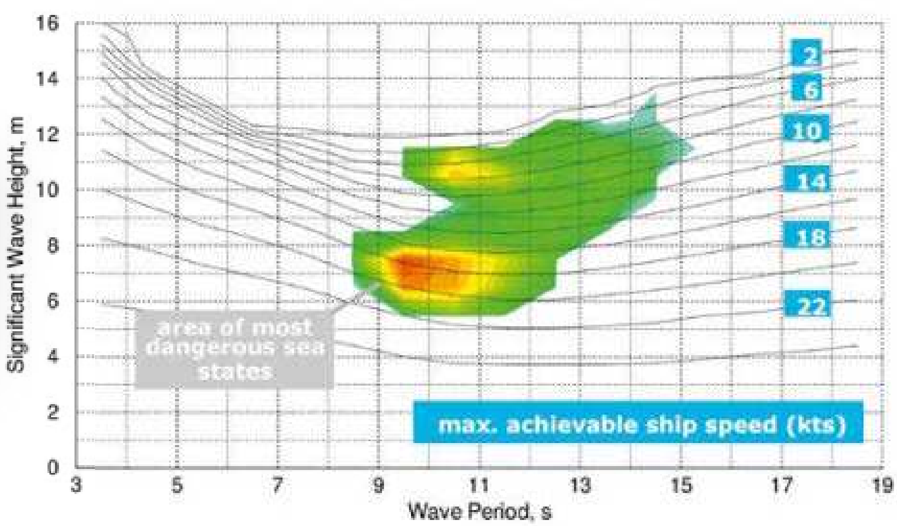

Sea states in which a large container vessel is at high risk of severe whipping.

SUCCESSFUL SURGERY

In an unprecedented endeavour, the ship manager Reederei NSB widened three of its Panamax-class container vessels. DNV GL, the class in charge, was on board.

Too young for scrapping, too old to compete: Roughly 500 Panamax-class container ships are currently less than ten years old, barely half their useful life. But facing overcapacities, low charter rates and fierce competition, the Panamax class is under intense pressure. Compared with state-of-the-art and much more capacious newbuildings, its prospects are dim.

This is mainly due to the way these vessels were designed. To pass the old locks of the Panama Canal, they were built with unusual dimensions – long and thin and with a large amount of ballast water to compensate the poor stability. "In addition, Panamax ships are equipped with stronger engines that achieve their highest efficiency when operating at higher speeds, rather than slow steaming, which is more common today," says Marcus Ihms, Ship Type Expert for Container Ships at DNV GL – Maritime.

So shipowners try to make their fleets more competitive by undertaking minor and major ship conversions (see below).

Reederei NSB of Buxtehude, Germany, caused quite a stir with the idea of widening three of its Panamax container vessels: *MSC Geneva, MSC Carouge,* and *MSC Lausanne* were widened in 2015, each over a period of three to four months. "No one has ever cut a container ship lengthwise from the superstructure to the bow to widen it," says Tim Ponath, Chief Operative Officer of Reederei NSB. "We are very proud of our team who demonstrated the viability of our concept."

Innovative and technically sophisticated, this concept was developed jointly by NSB and the Hamburg-based Technolog GmbH. After separating the fore and aft body from the cargo hold in dry dock, the cargo hold is cut in half lengthwise and pulled apart. The new centre sections are inserted and connected to the existing part. "The main idea behind this innovative method is cutting the hull in the least stressed areas and significantly increasing both the container intake and stability by widening it," says Lutz

OPTIONS FOR MINOR AND MAJOR CONVERSIONS

A changed economic environment calls for measures to make existing container tonnage originally designed for different operating conditions more competitive. A number of options are available.

Increase the draught
Increasing the draught, and thereby the deadweight, will allow the ship to take on more weight per container. Strength and stability considerations, the resulting visibility line and the location of pilot doors must be accounted for.

Heighten the deckhouse
A taller deckhouse will increase deck container capacity and improve the line of sight at the same deadweight. Appropriate lashing bridges and innovative methods to determine the cargo securing help to fully utilize the benefits.

Upgrade the lashing bridges
Installing lashing bridges or heightening existing ones improves stowage performance. This is often combined with a hatch cover upgrade to enlarge the stackweight. Structural re-approval of the substructure is necessary.

A stately lady, the widened *MSC Geneva* now boasts a 30 per cent higher TEU capacity at the same operating costs.

Müller, Senior Technical Consultant at NSB and one of the key initiators of the project.

Providing guidance

The conversion was carried out by Huarun Dadong Dockyard (HRDD), China. DNV GL, the classification society in charge of the ships, was involved from the early stages. "This kind of conversion is a major project," emphasizes Ihms. This means that all classification and flag state rules in effect at the time of conversion have to be observed. It is important to discuss with the flag state and the class, what rules must be adhered to under all circumstances, and what parts of the ship can be handled according to existing standards rather than new requirements.

"Our Class Note for Conversion of Ships provides the necessary guidance to owners as well as engineering companies during the design phase," Ihms points out. For example, in the case of *MSC Geneva* and her two sister ships, the anchor equipment had to be adapted, as a widened ship is heavier and offers more resistance to wind. "According to our well proven method, additional chain lengths can provide more holding force. Thereby, the retrofit of the entire winch system can be avoided without jeopardizing the anchoring capability," Ihms reports. From anchor equipment and ship strength and stability through to statutory compliance and cargo lashing, close collaboration between all project stakeholders was crucial for the success of this world premiere.

Photos: Reederei NSB, Hasenpusch

Added benefits

A conversion adds up to four container rows to the cargo hold, increasing the container capacity by about 30 per cent. In addition, it improves engine efficiency when combined with an optimized propeller, and bolsters stability. "Stability increases exponentially when you widen a ship," Ihms explains. As an added benefit, the required ballast water per loaded container could be reduced by half. The IMO Energy Efficiency Design Index (EEDI) achieved will equal that of a newbuilding and meet EEDI regulations as per 2025. The life-extending surgery will pay for itself within four years – so in the end it has all been well worth the effort, Ihms assures. **PL**

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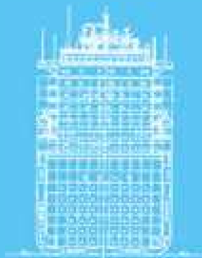
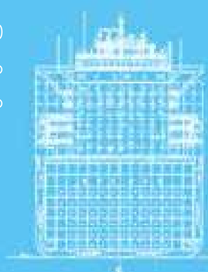
Lengthen the ship
Payload and cargo intake is significantly increased by adding a new midsection. This major conversion changes the ship's longitudinal strength in particular and requires comprehensive structural verifications.

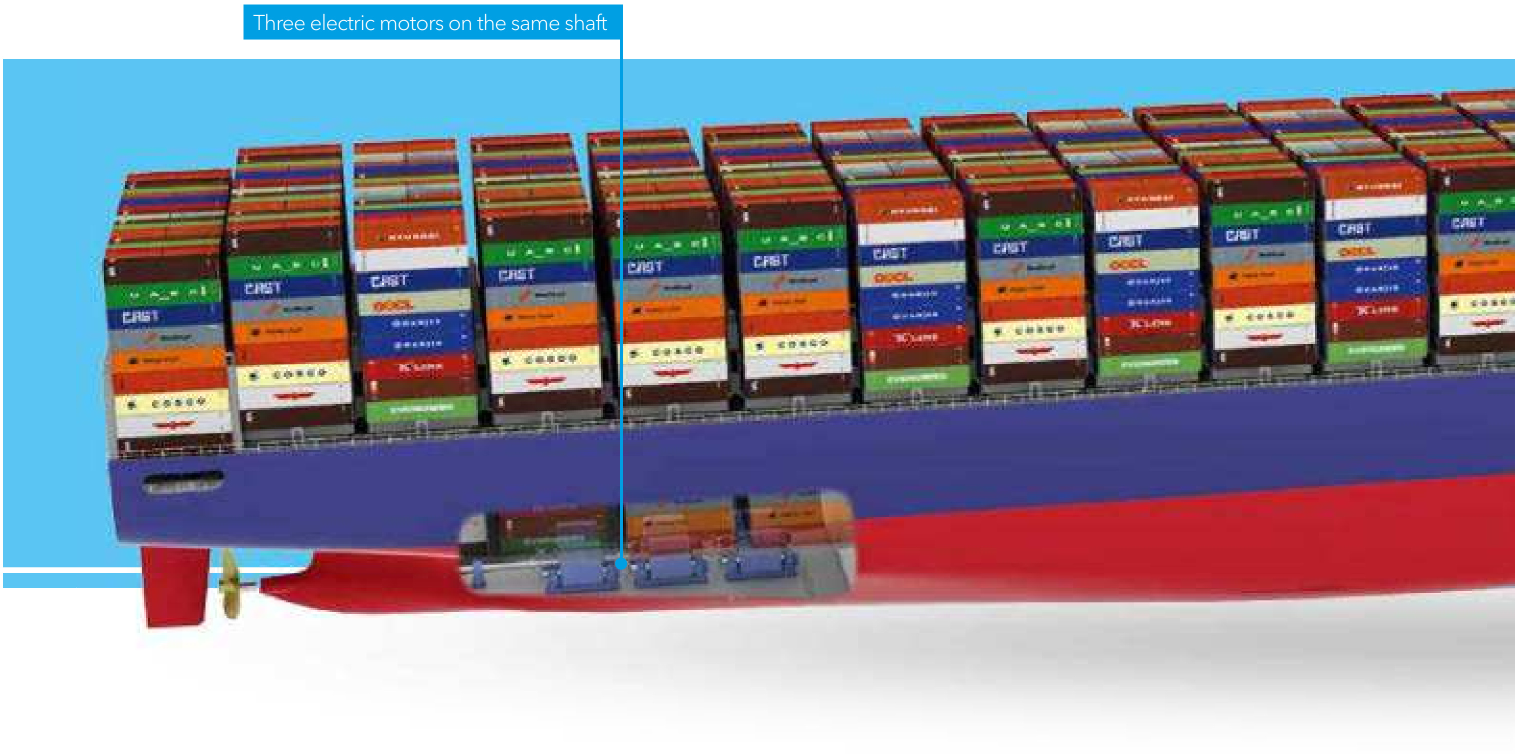
Widen the ship (at right)
Often combined with lengthening, this complex conversion means cutting the ship apart lengthwise to add a new centre line section. The cargo capacity and performance is boosted substantially.



original ship	*MSC Geneva*	after conversion
275.0	Length overall in m	283.0
32.2	Breadth in m	39.76
4,872	Nom. container intake TEU	6,296
59.4	EETI at 19 kn/(14 t TEU homogen. x 1,000 nm)[1]	44.9
27.1	Fuel oil consumption per container; per day in kg/(day*TEU)	20.1



[1] ISO cond., LCV 40 MJ/kg; in kg/(TEU*nm)



POWER WITHOUT PISTONS

GTT, CMA CGM (and its subsidiary CMA Ships) and DNV GL recently released a technical and feasibility study for a new mega box ship – the Piston Engine Room Free Efficient Container Ship (PERFECt ship). The concept vessel is LNG-fuelled, powered by a combined gas and steam turbine, and propelled electrically.

Exploring this novel configuration resulted in the partners identifying and analysing a propulsion concept that has the potential to offer a more efficient, more flexible and greener box ship design than current 20,000-TEU two-stroke, diesel-engine-driven ultra-large container vessels.

The study reveals considerable capacity gains while maintaining the same efficiency level. It demonstrates that the use of the clean LNG fuel harbours significant efficiency benefits which cannot be achieved by a conventionally fuelled combined gas and steam (COGAS) system. The efficiency of an optimized COGAS system may even exceed the efficiency of the oil-fuelled engine systems used today. At the same time, cargo capacity is increased by the use of LNG and not decreased as is the case with LNG-fuelled piston engine systems. In fact, the cargo capacity is higher than the capacity of a conventional oil-fuelled ship of the same size. This is the result of placing the COGAS turbine system at deck level close to the deck house and LNG tanks. Doing so makes nearly the entire space normally occupied by the engine room and the funnel structure available for the carriage of cargo.

Making use of electric power generation allows the power plant to be located away from the propulsion motors. For this reason, a conventional engine room is not needed any more. In addition, the three electric main motors, which are arranged on one common shaft, can run fully independently from each other, providing increased redundancy and reliability.

Gas-turbine-driven power production, utilizing a very clean fuel in combination with electric propulsion, provides a very clean technology which results in simpler and much more robust ship machinery systems. Implementing this approach can be expected to lead to new maintenance strategies similar to those applied in the airline industry, which may make it possible to reduce the ship's engine crew and save further costs.

What is more, optimizing the power plant by minimizing the steam turbine size, reducing power capacities and using condenser cooling as well as a two-stage pressure steam turbine and steam generator are all additional means to increase the net efficiency of such an optimized ship, which is expected to be significantly better than that of conventionally fuelled piston engine vessels.

In a next step, the project partners GTT, CMA CGM and its subsidiary CMA Ships, and DNV GL intend to work on optimizing the power supply system and the overall ship design.

Figure 1. Computer model of the proposed LNG COGAS-powered 20,000-TEU vessel.

Background

COGAS power generation is today the most efficient and economical way to convert fuel into mechanical power or electricity. Modern stationary COGAS plants running on natural gas achieve net plant efficiencies of approximately 60 per cent. This value cannot be reached by conventional ship diesel engines, whose efficiency is known to be around 52 per cent.

LNG is the ideal fuel for gas turbines. The high turbine outlet temperature allows for the installation of high-efficiency steam turbine cycles making use of the turbine exhaust gas.

The high power density and the modularity of COGAS plants, together with the electric propulsion concept, free up space for additional container slots, which make up for the slots lost because of the higher space requirement for LNG fuel compared with HFO.

The trend towards increasing the size of container ships and choosing relatively high design speeds drives up the power demand. In this scenario high-efficiency COGAS plants perform favourably and can be expected to be competitive with conventionally fuelled two-stroke diesel engine systems.

For these reasons, GTT, CMA CGM and its subsidiary CMA Ships, and DNV GL decided to take a closer look at the COGAS technology applied to container ships to determine its feasibility.

The reference ship

A conventional, HFO-fuelled 20,000-TEU container vessel (Figure 1) serves as a reference and basis for evaluation. Its main design parameters are similar but not identical to those of the *CMA CGM Marco Polo* (picture below).

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The HFO-fuelled reference vessel used in this study is comparable to the *CMA CGM Marco Polo.*

Photos: CMA CGM, DNV GL

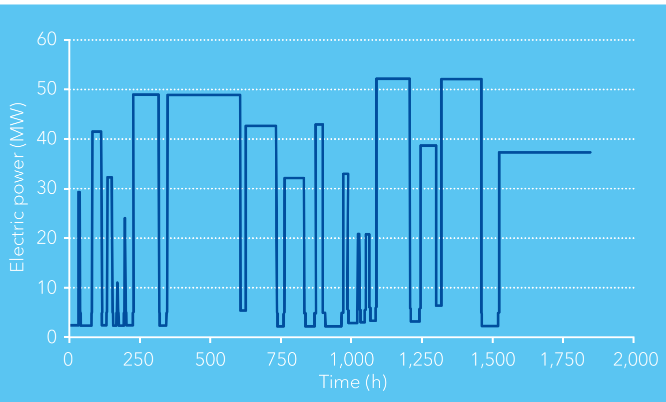


Figure 2: Operational profile for the ship.

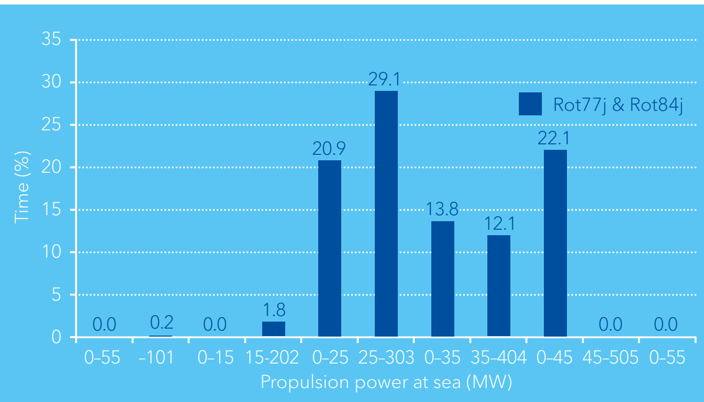


Figure 3: Histogram of the main engine's operational profile.

> The most relevant design parameters used for the study are:

- 90 MW total installed power
- Single propeller layout
- 65 MW at 22 knots at scantling draft
- Length overall – 400 m
- Beam – 59 m
- Scantling – 16 m
- Container capacity – approx. 20,000 TEU

The analysis of the overall ship efficiency and fuel consumption assumes a return voyage between Asia and Europe, including a realistic operating profile and all port calls. Figure 2 reflects the operating profile in terms of the chronological order of the ship's electric power demand, including sea, manoeuvring and port operation modes. The power demand of the ship is based on real-life data (Figures 3 and 4).

The electric power demand for the leg fluctuates widely as a result of varying ship speeds between the individual ports and the varying number of reefer containers carried. Naturally there is a big difference between the power demand at sea, which can exceed 50 MW, and the power demand in port, which is below 5 MW. This is also evident in the histograms in Figures 3 and 4, which represent the ranges and frequency of the required propulsion power and auxiliary power demand of the ship throughout the trip.

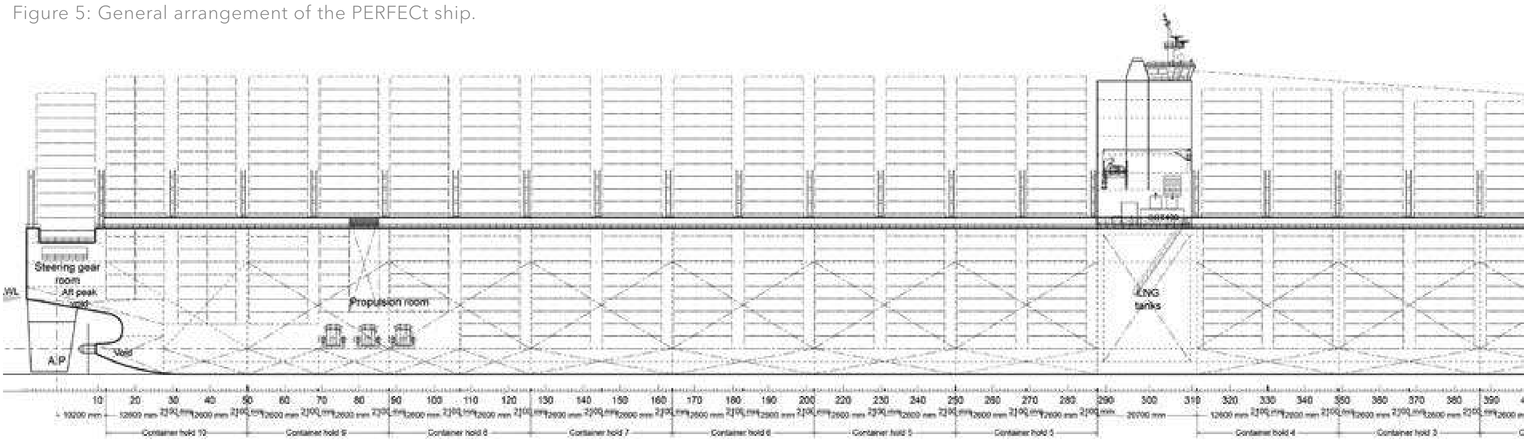
Apart from power demand, when designing a propulsion concept it is important to consider the ambient conditions which affect the performance of a power system, especially that of a gas turbine. For simulating the main sea areas along the trip, air temperature, relative humidity and sea water temperature values for the summer and winter seasons were used.

The conventionally fuelled reference ship was assumed to be equipped with a scrubber system. The comparison of both designs was based on total fuel consumption during the two-way voyage. Variations in terms of operating modes, power demand, efficiency under partial load, operation of auxiliary engines, etc. were taken into account. The final result showed that the overall efficiency of the COGAS system and the HFO-fuelled two-stroke engine system were very similar. It should be noted that the COGAS system chosen for the feasibility study was not fully optimized.

Additional efficiency potential could be leveraged by adopting the following optimization measures, among others:

- minimizing the steam turbine size to increase efficiency,
- reducing power capacities to run the system closer to optimal efficiency,
- optimizing the condenser cooling system of the steam turbine to increase turbine efficiency, and
- use of a two-stage pressure steam turbine and steam generator instead of the single-stage turbines assumed for the feasibility study.

Figure 5: General arrangement of the PERFECt ship.



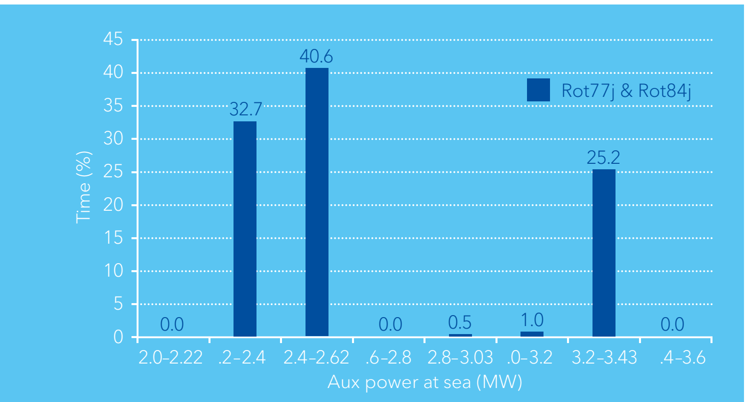


Figure 4: Histogram of the auxiliary engines' operational profile.

The net efficiency of the COGAS system is expected to be well above that of the conventional system. Additional efficiency gains could be achieved by optimizing the ship design and taking advantage of the flexibility resulting from the "missing" engine room.

The PERFECt ship

All power consumers on board are electric. The electric propulsion concept of the design allows for the decoupling of the power generator sets from the propeller motors. As a consequence a conventional engine room is not needed, and additional space is available for container slots. Figure 5 shows the general spatial arrangement of the ship. The following main design aspects are reflected:

Power distribution. The aim is to provide a minimum number of power generating sets (or gen-sets), most of them identical and all of them able to run in parallel in load sharing mode. This allows the high load during operating modes to be distributed so the power requirement per gen-set is still relatively low, which increases system efficiency. Installing identical gen-sets saves maintenance costs (consumables, spare parts management, etc.), minimizes crew training and facilitates parameter adjustment in various running modes.

Number, type and capacity of gen-sets. The electrical power generation capacity is adapted to power demand, accounting for the operating profile of the ship.

Dynamic power demand of the ship. The architecture of the power-generating system accounts for the fast response time required for power increases or decreases, including abrupt changes.

COGAS system simulation

To evaluate the COGAS system, the chosen layout was modelled and simulated using the DNV GL COSSMOS software. The detailed model was developed and calibrated using validated data; Figure 6 shows a simplified representation of the model. It consists of 209 components (main and auxiliary) involving 4,048 non-linear equations. The key system aspects included in the simulation are reflected in Figure 7.

One of the main challenges for the simulation – which were handled well by the powerful COSSMOS application – is the complexity and interdependency of the components. For example, the interaction between the power generation of the gas and steam turbines had to be accounted for by the simulation. At a given power demand, a specific load on the gas turbines has to be assumed as a starting point for iteration, with the remaining power demand needing to be provided by the steam turbines.

The power output of the steam turbines, however, depends on the exhaust gas parameters of the gas turbines, which are the power source for the steam generator, which powers the steam turbines. If the steam turbines cannot match the power

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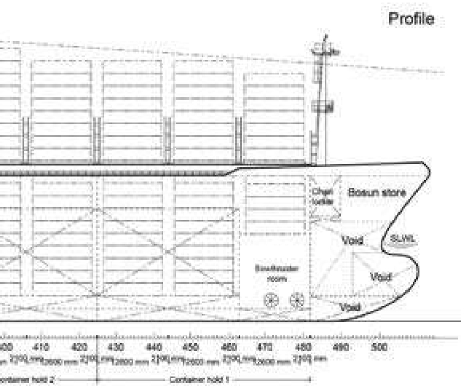
Photos: CMA CGM, DNV GL



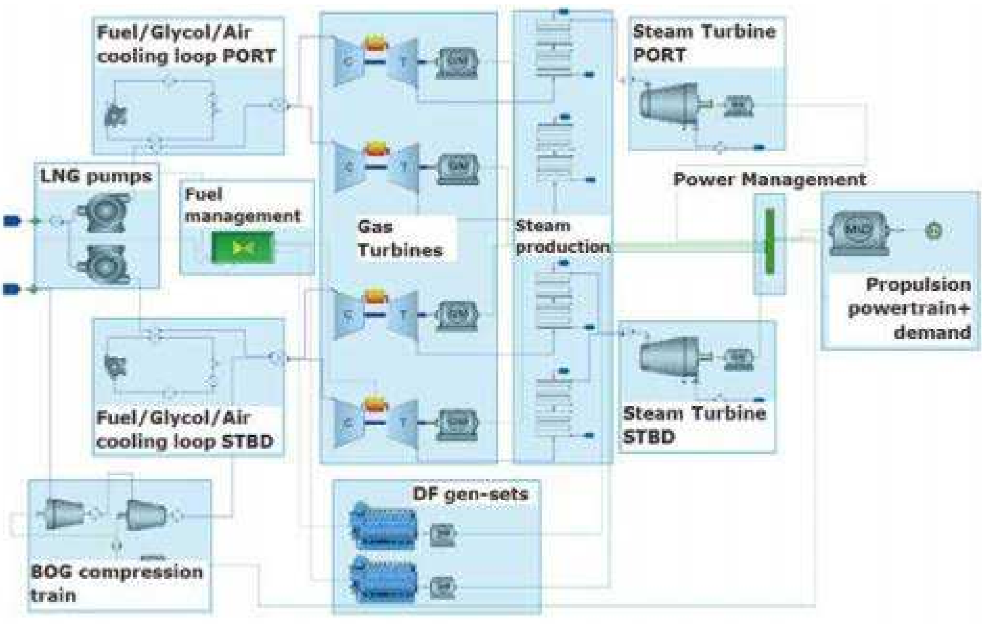


Figure 6: Piping and instrumentation diagram of COSSMOS model (209 components, 4,048 non-linear equations).

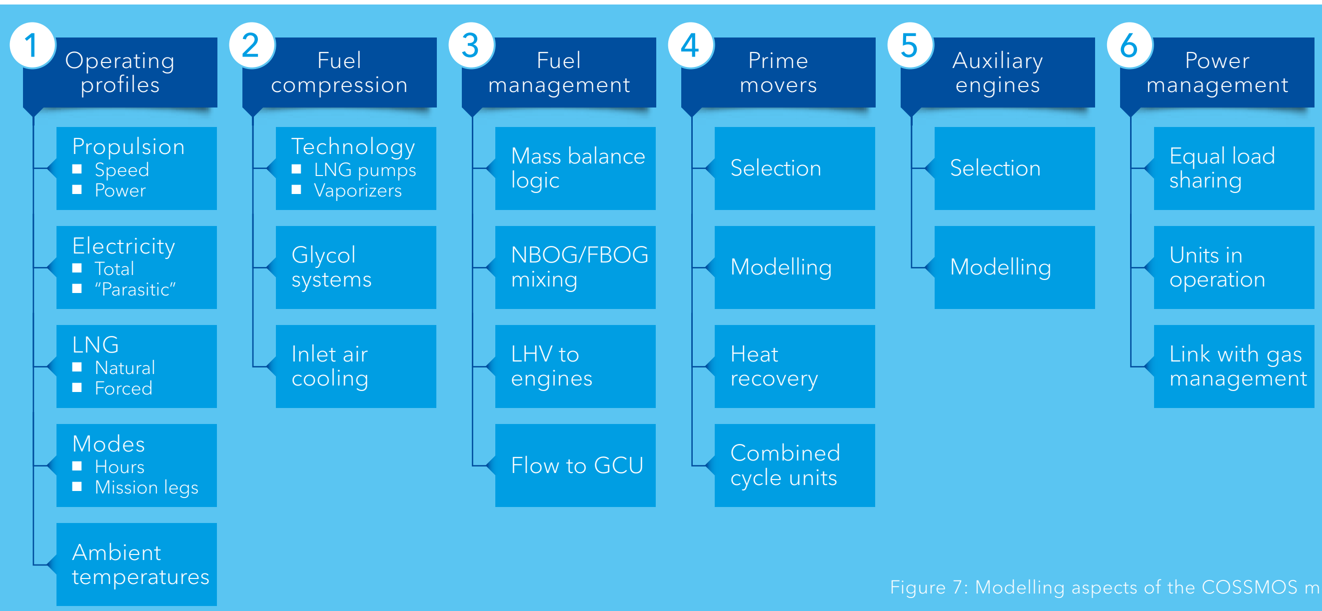


Figure 7: Modelling aspects of the COSSMOS model.

> demand, the load on the gas turbine must be increased; exhaust gas parameters and mass flow change accordingly until the power output of the steam and gas systems is balanced and the actual demand for ship propulsion, hotel loads, auxiliary loads and cargo-related loads is met. The balanced operational condition defines the LNG consumption of the gas turbines, thus determining the required heating demand for LNG vaporization. As this energy in turn is used for gas turbine intake air cooling, it again affects the gas turbine power, and thereby the load sharing balance. The same principle applies to the changing power demand for the cryogenic LNG treatment pumps, etc. This list could be continued through all components of the complex system.

LNG storage in membrane tanks

Two GTT Mark III Flex-type membrane fuel tanks with a geometric capacity of 10,960 m^3 each (100 per cent volume) are used for LNG storage. Figure 8 shows the principle of the insulation system and Figure 9 a Mark III tank installed on an LNG carrier. This design ensures safe operation under all weather conditions and at all filling levels, as well as high thermal performance and high volume utilization. The tanks are located near the midship section below the superstructure, and are approximately twice the size of an HFO tank with similar energy content.

The space above the tanks is large enough for installation of the COGAS system as well as crew accommodation, hence no engine room is needed at the aft of the vessel (see general arrangement plan in Figure 5). As a result, the ship gains approximately 300 container slots compared to the HFO-fuelled reference ship.

Global strength

Without an aft engine room island, the question of global strength had to be evaluated to decide on the feasibility of the concept. DNV GL performed the global strength analysis based on a 20,000-TEU generic standard container ship design which was modified in the aft part by removing the machinery room and decks and adding lower engine room decks for the electric propulsion machinery. On top of the deck, container spaces were incorporated into the hold. The original main engine foundations were replaced by smaller foundations for the electric propulsion engines (Figure 10).

Both designs – the generic standard design and the simplified alternative design – were subjected to finite elements analysis with respect to hatch opening deflections and movements, stress evaluation of the whole vessel, and hatch corner fatigue. The analysis indicated that the modified design needs to be reinforced at several locations to compensate for the reduced torsional stiffness of the new aft ship in the absence of a stiffening engine room structure.

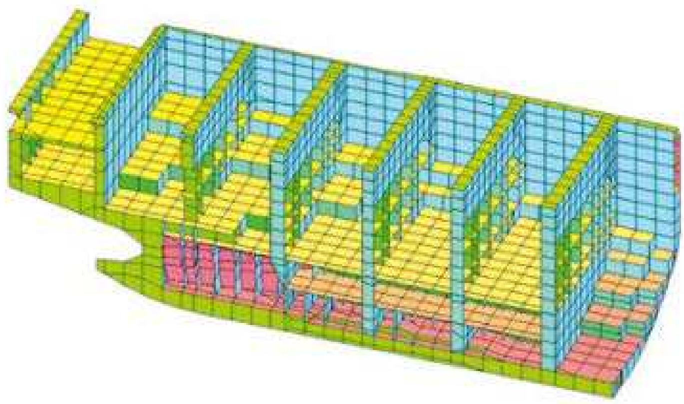


Figure 10: Finite element model of the PERFECt project aft ship.

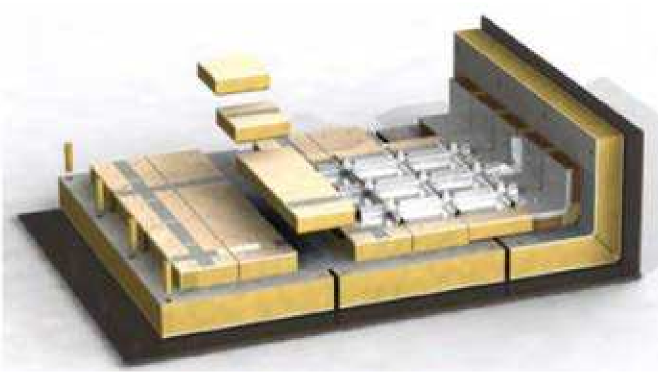


Figure 8: Mark III principle of the insulation system.

Figure 9: Mark III tank installed on an LNG carrier.

A qualitative assessment performed as part of the study did not produce any evidence of the modified aft ship creating major problems regarding the ship's strength.

The diagonal hatch opening deflections resulted in higher – yet controllable – values. Maximum hatch cover movements increased, which means that the affected holds require a modified hatch cover design (e.g. five-cover design) or a stiffer hull design. In the midship areas the strength limit was partially exceeded, with potential buckling occurring in the inner and outer bottoms. Here the moment of inertia or the plate thickness in the critical regions would need to be increased. Some container benches in the aft and the new propulsion engine room would likewise need to be reinforced.

Finally, to examine hatch corner fatigue DNV GL calculated all corners on the vessel. Results showed that all but one corner could be controlled by maintaining the radius and adding plate thickness. The most critical corner was on the upper deck, where the supporting main engine room deck was lacking. Here the design would require a keyhole or alternative solution.

In summary, the required modifications are mainly attributable to the fact that the study was based on the dimensions of the conventional two-island design with less torsional deformation in the aft part. The higher torsional deflection of the hull generates higher stresses in some locations, requiring adjusted scantlings. As an alternative solution to stiffening, a five-part cover could be considered for some bays. Calculations indicate that the additional hull steel work would change the hull costs only marginally.

Photos: DNV GL, GTT

CAPEX and OPEX

For the cost vs benefit assessment, the investment costs for the PERFECt LNG-fuelled ship were compared with those of the conventionally propelled ship, taking into account the costs of items added to or eliminated from the base design. This includes added costs for items such as:

- membrane tanks,
- gas and steam turbines,
- fuel gas handling installations and
- structural reinforcements (no aft engine casing).

Conversely, some cost items of the two-stroke engine system do not apply to the PERFECt design and can thus be subtracted, such as:

- no scrubber required,
- reduced cooling system capacity,
- simplified cooling system and
- no HFO treatment or tank heating required.

All things considered, the capital expenditure (CAPEX) for the COGAS ship is estimated to be 20 to 24 per cent higher than that of a conventionally fuelled vessel. The outcome of the operational expenditure (OPEX) comparison largely depends on the difference in fuel price, the added income earned by the additional container slots and the savings achieved by higher system efficiency if applicable.

Currently, the LNG price on the European spot market is nearly identical to the HFO price (as of 29 July 2016; IFO 380: 6.12 $/mmBTU = 235 $/t; Gas TTF: 4.67 $/mmBTU [lhv]). In a developed market, the distribution costs may be below 2 $/mmBTU. In a business case using HFO plus a scrubber as a reference, the higher operating costs of the COGAS vessel would have to be compensated either by a larger difference between the gas and LNG prices, or by additional efficiency improvements and the added revenue from the extra container slots.

The results of the feasibility study, including the CAPEX and OPEX calculations, have encouraged the project partners GTT, CMA CGM and its subsidiary CMA Ships, and DNV GL to plan a more detailed evaluation of the overall system in a follow-up project. ■

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FRESH DELIVERY

Dole continues its fleet renewal programme with three specialized refrigerated container vessels. *Dole Pacific* and her recently launched sister ships *Dole Atlantic* and *Dole Caribbean* incorporate the latest energy-saving technologies. Hyundai Mipo Dockyard and DNV GL have been on board from the early stages of the project.

Renowned for its prolific output of product tankers and bulkers, the South Korean Hyundai Mipo Dockyard has shown a determination in recent years to develop business in higher-value-added and more specialized sectors of the market. Dole's 27,500 dwt reefer ships incorporate the latest in energy-saving technologies, minimizing environmental impact through innovative design and operational practices.

Completed in about eleven months after initial steel cutting, the ships have main dimensions of 190 m overall length and 30.4 m breadth, and are powered by an MAN B&W 8L70ME-C8.2 two-stroke engine. Tunnel thrusters at the bow and stern ensure efficient berthing without recourse to tugs in all but extreme conditions.

The high electric energy demand arising from payloads of reefer boxes necessitates a large generator installation and robust electrical system. This has been met by an outfit of four diesel generator sets using eight-cylinder H32/40- and H25/33-type engines from Hyundai Heavy Industries' HiMSEN range.

Innovative features

Two 40-ton, on-deck Liebherr electro-hydraulic gantry cranes have been installed on the ships, enabling them to call at a variety of ports. Thanks to the specially developed C-design, the Liebherr CCB crane weighs considerably less than other conventional gantry crane solutions for transport vessels and provides the following advantages:

Dole Pacific is part of Dole's reefer fleet rejuvenation campaign. The 27,500 dwt vessel can carry up to 770 refrigerated 40 ft containers for fresh fruit and vegetables.

- High speed due to C-form (up to 50 containers per hour)
- High reliability due to two independent hydraulic power packs
- Low construction height ensures maximum vessel stability
- Foldable side arms for a total outreach of 55 m

The two cranes on deck were one of several reasons to opt in favour of the sponson structure for the ships. This resulted in a very large bow flare angle. DNV GL conducted a direct evaluation for the bow impact. The calculations were performed using global FE analysis.

Cooling the ship's hold efficiently and ensuring proper ventilation of fumes pose unique design challenges. While air cooling systems are normally installed on board reefer container ships, the designers of the Dole series chose a water cooling system as the most effective solution. The RCP (Refrigerated Container Stowage Positions) class notation verifies the performance of the installed system, which dissipates the heat from the cooling systems of as many as 770 refrigerated 40 ft containers. Compared to air cooling systems, water offers a number of benefits:

- Low cargo hold temperatures/low energy consumption
- Minimized hold ventilation (only 12 to 15 per cent as compared to systems for air-cooled condensers)
- Air distribution systems inside holds may be dispensed with
- Reduced noise emissions
- Reduced impact on structural strength
- Increased reserve capacity for CRU

The three new vessels are replacing smaller container ships in service between San Diego, Guayaquil (Ecuador), Paita (Peru), Caldera (Costa Rica) and Puerto Quetzal (Guatemala). They are operated and managed by Reefership Marine Services. **SA**

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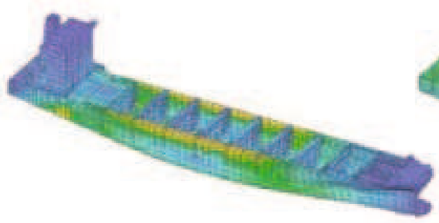
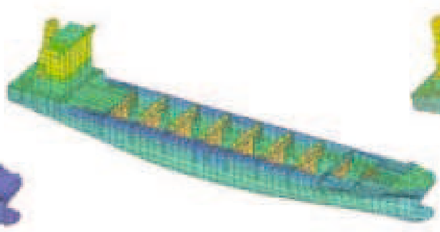
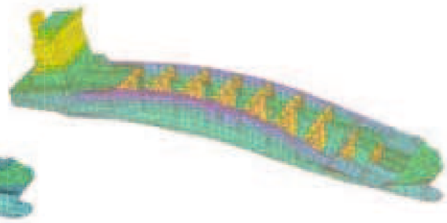


Using global Finite Elements (FE) analysis, DNV GL investigated the effects of the extreme bow flare angles on structural strength.



The "sponson" design was necessary to accommodate the gantry cranes, which allow the ships to be loaded at any port.



The FE model evaluations used various extreme load scenarios to verify the stability of the ship and its unusual bow section.

THE FRESHWATER COOLING SYSTEM

- Three cooling water pumps (one standing by), capacity approx. 30 l/min. per FEU
- Two plate heat exchangers each with a capacity of approx. 22 kW/Container
- Temperature of freshwater supply ~28 °C (in any case > 15°C), max. 36 °C @ 32 °C seawater temperature
- Heating system for carriage of bananas during the cold season
- Automated vents for cooling water piping system and manual check valve
- Cooling water connections for CRU as described in ISO 1496-2
- Cooling water bypass with orifice for part loading condition
- Flexible hose and ball valve fitted in cooling water supply and return line

Quick-disconnect, flexible hose connections for the cooling water system.

SAFER, SMARTER, GREENER

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