Ultra Large Containerships

Technology for higher safety and improved performance

A technology report from Bureau Veritas Marine & Offshore

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BUREAU VERITAS

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TECHNOLOGY REPORT

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THE GROWTH OF CONTAINERIZATION AND SHIP SIZE

Seaborne container trade has grown dramatically in the last 25 years. Tonnage afloat has increased by a factor of eight, from 30.7 million deadweight metric tons (DWT) in January 1992, to 245.6 milion DWT by the beginning of 2017*.
Today, more than ever, world trade is utterly reliant on Containerships.

Not only has the fleet grown by a factor of eight in the last quarter of a century, but ship size has also increased dramatically. A large containership in 1992 was 4,000 twenty-foot equivalent units (TEU). Today, the largest ships have gone beyond 20,000 TEU. In September 2017, orders for twenty 22,000 TEU ships were placed on successive days – representing a total additional box capacity of 440,000 TEU.
Box ships are bigger because the market wants efficiency. Clients of container lines want a more competitive, faster and cleaner service. Lines are looking to reduce costs, meet environmental regulations, streamline logistics chains, and maintain or improve safety margins. So ships have kept getting bigger.
But demand for ultra-large Containerships, with their long and slender hull forms - and with large deck openings for container bays - has presented technical challenges that must be understood in the context of three key factors: demand to load more containers with greater flexibility, the need to reduce environmental impact and the need for confidence in the structural strength of large containerships.

**Source: Clarksons Research*

KEY TECHNICAL CHALLENGES FOR ULTRA LARGE CONTAINERSHIPS

Optimize cargo

Reduce environmental impact

Confidence in the structural strength of large containerships

The purpose of this report

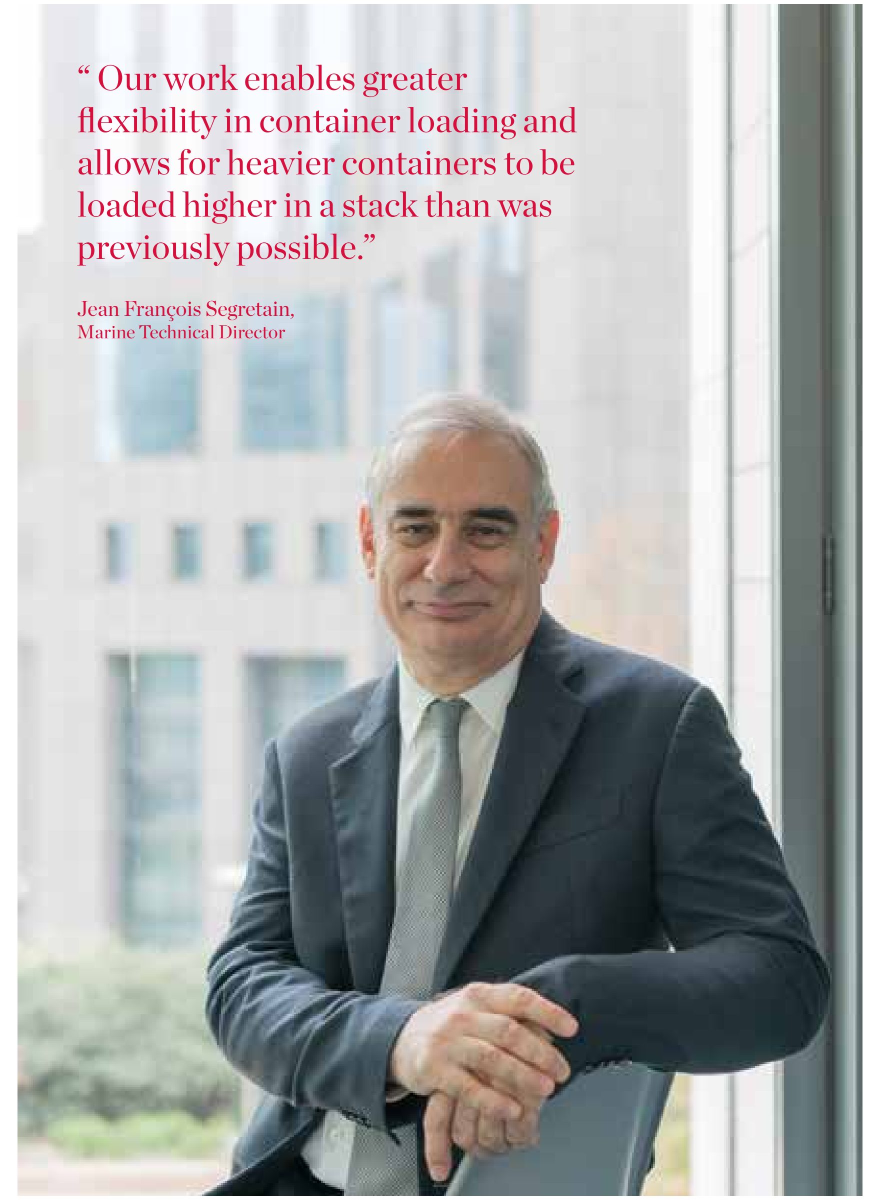
While demand to load more cargo, reduce environmental impact and help ensure structural strength are not unique to large containerships, their requirements need specific technical expertise to be delivered. This report reviews the work that Bureau Veritas has carried out recently to provide better containership rules. It provides insight into understanding what is required to use LNG as fuel – one of the options to meet the environmental challenges of today and tomorrow - and what needs to be considered to carry out gas bunker operations on large boxships.

Underpinning everything, it introduces some of the work that forms our understanding of the structural strength of large containerships.

Good rules + better software = more cargo + flexibility

VERISTAR LASHING 3.0

LOAD MORE CONTAINERS WITH GREATER FLEXIBILITY



“ Our work enables greater flexibility in container loading and allows for heavier containers to be loaded higher in a stack than was previously possible.”

Jean François Segretain,
Marine Technical Director

Technical challenges and solutions to address safety and operational requirements

Bureau Veritas structural research and development, which has led to new containership Rules, has also led to a better understanding of containership cargo capacity. This has enabled the development of Bureau Veritas's container lashing software – VeriSTAR Lashing 3.0. Bureau Veritas has been at the forefront of understanding how to solve technical challenges to meet the requirements of ultra-large containership design. This report describes the results of research and development work carried out by Bureau Veritas structures and hydrodynamic experts that has led to a better understanding of the forces at play in large containerships - in terms of hull structures, cargo stowage, and propulsion systems.
This work enables greater flexibility in container loading and allows for heavier containers to be loaded higher in a stack than was previously possible.
Bureau Veritas's LNG track record and class leadership in gas-fueled shipping provides insight into key issues for gas-powered ULCSs.

TECHNOLOGY REPORT

STRUCTURAL EXPERTISE

Optimized structures and lashing

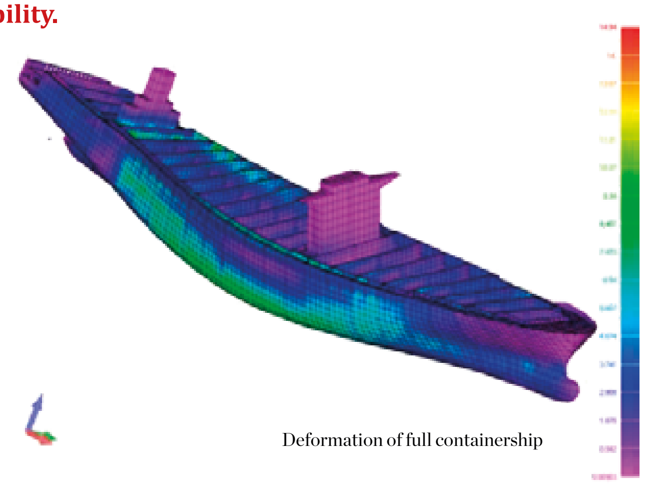
Due to their long, slender hulls, which result from their operating speed requirements and the need for large deck openings to accommodate container bays, Containerships present specific structural challenges. As containership size increases, so too do these structural challenges.

The revised design wave loads that now underpin containership rules have optimized ship structures. But an additional and highly significant consequence of their application is that they now also allow for optimized container lashings, offering operators much more flexibility.

The new containership structural Rules and VeriSTAR Lashing software are the result of a better understanding of the physics and engineering requirements of large containerships.

Overall, acceleration loads applied in the new rules (the surge, sway, heave, roll, pitch and yaw motions of the ship) have been more precisely determined and, usually, reduced. Reduced accelerations means less force acting on the lashing rods, allowing operators to optimize cargo capacity, not just in terms of being able to add more containers, but also in how the containers are distributed within each stack. This has the potential to save them significant sums of money – and time.

With reduced accelerations, both ship structure and container lashing are optimized.



Deformation of full containership

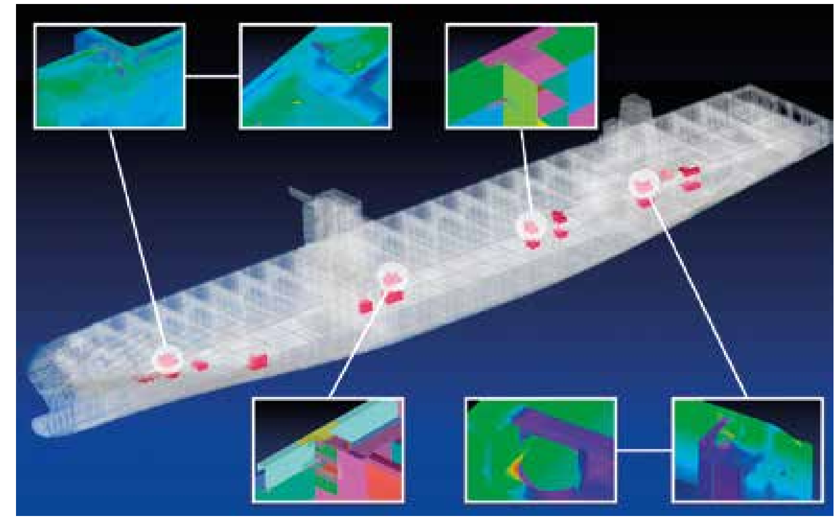
WHISP notation - Understanding whipping and springing

Hydro elasticity is a complex technical challenge that requires, in order to be properly assessed, state of the art methodologies and tools. Whipping and Springing phenomena may have important effects on the hull girder strength and fatigue of Ultra Large Containerships, requiring appropriate identification and evaluation at the early design stage.

Bureau Veritas expertise in assessing the phenomenon of whipping and springing dates back to the 1970s. Bureau Veritas developed industry leading capability and in house software tools that have been continually updated. These tools provide the capability to perform hydro-structure coupling and hydro-elastic simulations on both frequency and time domains, addressing both weak and strong non-linear effects. The results are validated through an extensive set of model tests and full scale measurements.
This proven expertise resulted in the introduction in the Bureau Veritas rules of the WHISP additional service features, reflecting the necessity of a whipping and springing assessment for large containerships.

Within the new Rules, there is now a chapter about carrying out lashing calculations based on new accelerations. And to enable operators to apply these calculations as efficiently as possible, Bureau Veritas has created new container securing and lashing software, VeriSTAR Lashing, the culmination of more than two years' work.

Christophe Chauviere, Head of Development for Bureau Veritas's Marine and Offshore division, says: *"The strength of VeriSTAR Lashing is that it is linked to direct and powerful computation using state-of-the-art hydrodynamics and real sea states – the same design wave computation that underpins the structural rules. In the past, calculations for lashing were based on empirical formulae. Today, better calculations mean reduced accelerations and more flexibility."*



The thickness of the steel on the main deck in a 22,000 TEU box ship will be 80 mm.

Christophe Chauviere,
Head of Developpement Departement,
Bureau Veritas Marine & Offshore

A key feature of the software is that it takes account of the additional forces on the lashing bars and rods resulting from vertical and horizontal gaps in the twist locks, and between containers. The influence of gaps is now clearly understood, though previously it had been disregarded.

Flume (anti-rolling) tanks

The new Rules also cover the use of anti-rolling or 'flume' tanks, which can further optimize lashing arrangements by reducing the ship's roll motion. The tanks contain water, and it is the movement of this water that compensates for the ship's motion.

Work carried out by Bureau Veritas to compute the forces applied by the motion of the fluid in the tanks has found that roll motion can be reduced by up to 30%.

The next step is to investigate whether owners and operators wish to install flume tanks in new builds, where they can be integrated into the design at an early stage.

Before and after Applying VeriSTAR Lashing 3.0

The ability to optimize cargo capacity, minimize container movements and have greater flexibility in weight distribution is now a possibility with BV Lashing 3.0
Heavier cargo can now be loaded higher in a stack than previously. Calculations can be made for specific sea state areas or for world-wide trading.

Two single stack examples (18,000 TEU, 400m LOA 54m beam ULCS):

Bay 42 (midships)

+ 6 tons

11 tier stack of FEUs*
allowing 166 tons instead of 160

Bay 90 (aft)

+ 12.5 tons

11 tier stack of FEUs*
allowing 171 tons instead of 160

*FEU: Forty foot Equivalent Unit

These are specific examples of increased weight permissible and provide a general indication of the potential improved performance. Bureau Veritas experts would be happy to provide an analysis of the benefits of applying the Lashing 3.0 software on a specific ship/condition case.

For a given stack and a lashing configuration, VeriSTAR Lashing 3.0 immediately checks:

Lashing rod effort vs Safe Working Load,
Twistlock tensile and shear load,
Loads in container fittings,
Racking and vertical forces in way of both container sides (door and wall),
Stack reactions

GAS EXPERTISE

REDUCING ENVIRONMENTAL IMPACT

LNG is one of the fuel choices to meet the global Sulphur cap when it is introduced in 2020. The others are low Sulphur heavy fuel oil, distillates or to use exhaust gas cleaning systems (scrubbers). Until November 2017 uptake of LNG as a marine fuel by boxships had been limited to a number of relatively small containerships ordered in the USA for Jones Act trades and four HFO to LNG conversions (WES Amelie, conversion completed in 2017, and three others announced).

An LNG-fueled future for ULCSs

The largest Containerships in operation today trade between Asia and Europe. Heavy fuel oil (HFO) and marine gas oil (MGO) bunkering options are available at most or all ports used. The maximum bunker capacity of these ships is around 15,000 cubic meters (cbm).

However, a fully optimized, modern ULCS with a cargo capacity of 22,000 TEU, designed to run on LNG, will likely need the option of bunker capacity for a full west-to-east and east-to-west rotation. This covers a range of about 27,000 nautical miles and a voyage duration of about 80 days. For such a range and voyage duration, a ULCS will need an LNG bunker tank capacity of 18,000 to 20,000 cbm. The ability to complete a full round trip will be dependent on the current and future availability of LNG bunkering infrastructure to provide the required quantities of LNG. While supply of bunker stems up to 7,000 cbm has been developing fast, a step up in scale will now be required to meet demand for stems up to 20,000 cbm.

As a ship burns its fuel, LNG tank volumes will decline, potentially through the full spectrum from a full to an almost empty tank. This requires attention to ensure that tank arrangements, design and construction are able to withstand sloshing loads. It also requires optimized management of boil-off gas.

November 2017: CMA CGM has ordered nine 22,000 TEU gas fuelled containerships.

Announcement of nine LNG fuelled 22,000 TEU containerships for CMA CGM: a breakthrough development.

The ships will be built at two China State Shipbuilding Corporation (CSSC) yards: Hudong-Zhonghua Shipbuilding (Group) Co., Ltd. and Shanghai Waigaoqiao Shipbuilding Co., Ltd, under BV classification. The Winterthur Gas & Diesel (WinGD) 12-cylinder X92DF engines ordered will be rated 63,840 kW at 80 rpm, making them the most powerful gas and dual-fuel engines ever built.
The new ships will each have a bunker capacity of 18,600 cubic metres (cbm) in a GTT designed Mark III membrane tank. Bureau Veritas was closely involved in the feasibility of the design together with the shipbuilding group CSSC and GTT.

Supplying large gas-fueled Containerships with LNG bunkers –safely

To minimize operational disruption, large Containerships need to be able to take on board bunkers while alongside and while loading and discharging cargo. Taking on board 15,000-20,000 cbm of LNG will take at least 12 to 15 hours* from start to finish including: connection, inerting, testing, LNG transfer, purging, inerting again, and disconnection as well as delivery of a bunker delivery note with all requirements of the IGF code. So, a major port call requiring up to 40 hours for cargo operations is more than adequate for bunkering operations.

Martial Claudepierre,
Global Technology Leader
LNG as Fuel

*1,200 cbm/h using two lines for LNG and one for vapor return

The main challenge to be addressed for the ship-to-ship transfer of LNG is to identify and allow for a reasonable safety zone while minimizing the impact on loading operations as much as possible. Risk assessment will determine the necessary size of the safety zone and, if deemed necessary, will be supplemented by a gas cloud dispersion model analysis (using a deterministic approach) as per ISO 20519 and SGMF Safety Guidelines for LNG bunkering.

However, simultaneous cargo and bunkering operations do not necessarily increase levels of risk. Moreover, a safety zone is not necessarily the same as an exclusion zone. But within the safety zone it is necessary to control, monitor, detect, protect against, and mitigate any consequences of potential LNG leakage, according to certain scenarios. This must take into account operational experience, appropriate crew training, terminal operator information, safety procedures, and the reliability of cryogenic transfer equipment allowing for the possibility of using entire vacuum insulated double wall transfer lines as have been developed for passenger ship LNG bunkering operations.

In summary, with proper care, appropriate precautions, trained personnel, and established procedures, regular LNG bunkering is not significantly more complicated than conventional HFO bunkering. Furthermore, conventional pollution prevention is not a risk, and oil spill prevention measures are not required.

Fuel quality

The quality of conventional HFO bunker fuels has long been a major factor to manage in the shipping industry. And there have been a variety of quality issues to be managed and tested to ensure that required and contractual standards are met.

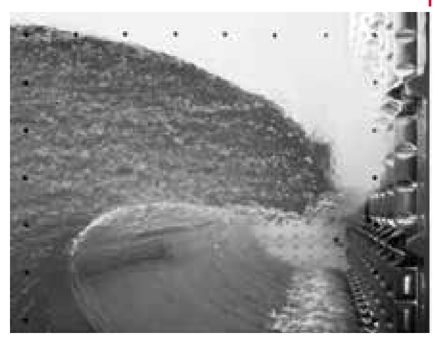
One key factor in establishing the quality of LNG as fuel is the methane number (MN). But it is not the only factor. Temperature is also important, as well other parameters such as, to a certain extent, the Wobbe index, where dual fuel (DF) boilers are used. Custody transfer from the LNG bunker vessel to the receiving ship is also part of this, as it must quantify the energy transferred and deduct the vapor return quantity. The use of Coriolis flowmeters and spectrographs on board LNG bunker vessels eases transfer of commercial data and will help eliminate potential disputes. An ISO standard for LNG fuel quality is currently being developed to select a comprehensive method for MN calculation. Bureau Veritas is involved in this work

A broad group of stakeholders is involved in LNG bunkering safety: ISO, EMSA, IACS, IAPH, CSA, USCG, SGMF and SEA/LNG are all working - together where appropriate - in order to secure a strict application of safety guidelines and international standards and, where possible, ensure the harmonization of rules and standards. Bureau Veritas is playing a major role sharing its experience and supporting the industry in developing safe LNG bunkering arrangements, technology, standards and operations.

LNG as fuel bunker containment systems for Ultra-Large Containerships

60 years of LNG experience have enabled Bureau Veritas to develop the assessment tools to understand design requirements for large-capacity LNG bunker tanks

The significant quantities of LNG required for ultra-large ships require large storage capacities, and one major decision is whether a design should be based on either one large bunker tank or two (or more) smaller tanks.



Full scale impact wave at a low partial filling in a membrane tank (SlosHel Project).

Sloshing

The requirements of trading Containerships will be that the tanks will have to be designed to withstand sloshing impacts in all partially filled conditions.

What is sloshing?

Sloshing of LNG is a hydrodynamic phenomenon that can lead to high magnitude impacts on walls with potential consequences on the containment system response. Sloshing is primarily an issue when LNG tanks are void of internal structure, and it occurs in partially filled conditions.

Bureau Veritas has been researching and responding to the challenge of creating containment systems in LNG carriers, FLNGs, FSRUs and, more recently, for bunker tank designs.

Sloshing is a critical safety issue to be addressed.

On ULCSs, with their large beams, a tank spanning the breadth of the ship is potentially subject to heavy sloshing impact in beam seas when in partial fill condition.
However, proper assessment, calculation and, if required, adjustments to the design of the tank can address the risks of sloshing. Bureau Veritas has a methodology to assess loads and determine appropriate design responses requiring a strengthened containment system.

3-step sloshing assessment and calculation process

1. Seakeeping analysis - to calculate the motions of the ship and, consequently, tank motions
2. Sloshing model tests (carried out by the designer) and computational fluid dynamics (CFD) calculations by Bureau Veritas (both using calculated tank motions) are carried out in order to determine sloshing loads
3. Sloshing loads applied to entire containment system

Seakeeping Analysis

Initially, the entire range of the ship's operational loading conditions is ordered in different groups reflecting different operational conditions, such as variations in draft. For example, at a given draft, the worst loading condition regarding sloshing is that associated with the greatest metacentric height (GM) and the lowest natural roll period.

Next, coupling effects between liquid motions inside the LNG tank(s) and the ship's motions need to be taken into account.

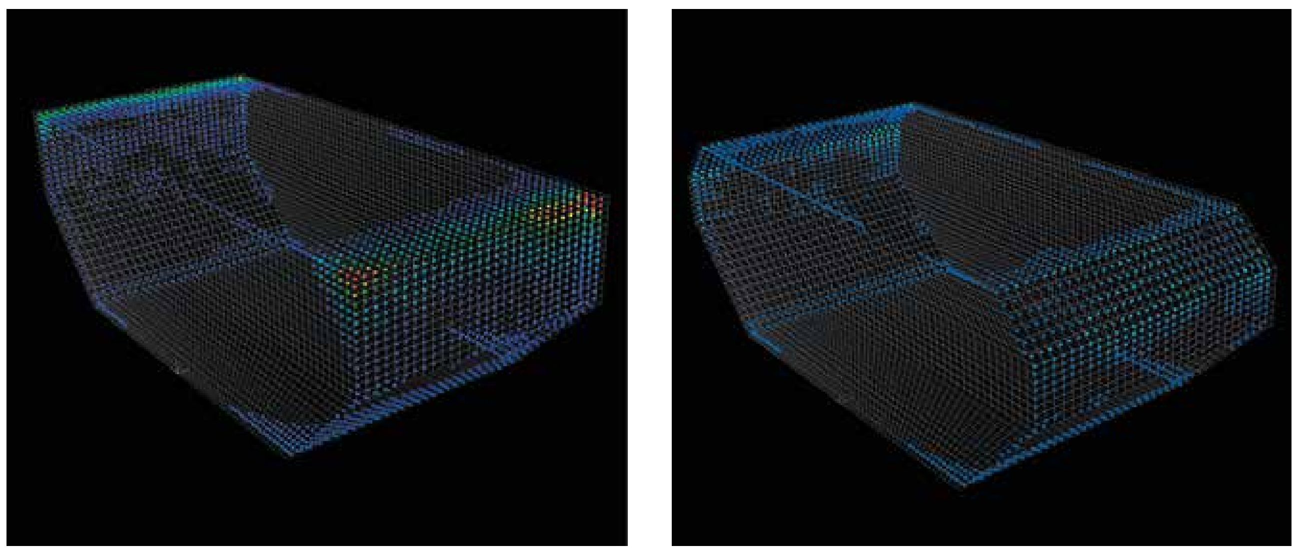
For one-row tank arrangements (i.e., one tank spanning the full beam of the ship), coupling must be taken into account (using HydroSTAR®), which is not the case for a double-row tank arrangement. A double-row tank arrangement will also be less sensitive to sloshing than a one-row tank as the tank's natural periods (for all filling levels) are out of the range of the ship's roll periods. So, a one-row tank will require a strengthened cargo containment system.

Sloshing Analysis

In addition to sloshing model tests to be submitted by the designer, Bureau Veritas carries out its own CFD calculations for sloshing model test verification and to derive the loads for the inner hull and pump-mast strength assessments. These CFD calculations are complementary to model tests. CFD calculations, by recording all data at each time step, in all cells, provide a total representation of the sloshing impacts on all the tank walls.

Sloshing loads applied

The final step is to apply sloshing loads to the entire containment system, including the inner hull and the pump mast inside the tank, for strength assessment against Bureau Veritas's Rules.



Reducing sloshing impact: membrane containment tank without upper chamfer (left); and with chamfer to reduce impact loads (right).

IN-DEPTH RESEARCH

CONFIDENCE IN THE STRUCTURAL STRENGTH OF LARGE CONTAINERSHIPS

Behind the development of Bureau Veritas's Rules is sophisticated work undertaken by the Research Department

Quentin Derbanne,
Head of Research Department,
Bureau Veritas Marine & Osffshore

Led by Quentin Derbanne, the Research Department's mission has been to find a better understanding of what is actually happening to ships during operations – understanding the forces at play in a seaway and building a clearer picture of the combined impact on hull structures and on container stacks.

Crucially, the work has included analyses of loads on a large database of 74 vessels, in fact the largest ever to be used in formulating Rules.

With the focus firmly on precision, the results have led to greater certainty for designers and owners, and have introduced extra operational benefits related to the increase of cargo carrying capacity.

Underpinning both the Rules and the software is Bureau Veritas's powerful 'equivalent design wave' methodology, which has been used to compute much more realistic sea loads, pinpointing those waves that will exert the most extreme stresses on ship structure, as well as those that will most affect fatigue strength.

The work to revise the Rules

The search for greater precision

S11A

The work to revise the Rules has been all about precision. The higher the precision, the greater the certainty, and it is this certainty that Bureau Veritas wishes to provide to clients designing and operating Containerships.

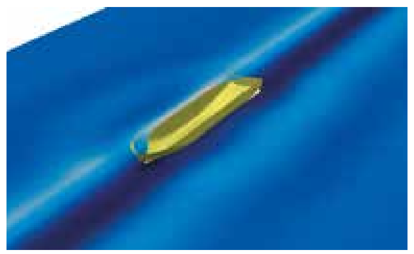
The work started following Bureau Veritas's involvement in the IACS working group that culminated in the Unified Requirement S11A - Longitudinal Strength Standard for Containerships, which came out of the MOL Comfort disaster. With class societies required to incorporate the standard into their Rules, Bureau Veritas took the opportunity to re-assess everything. When incorporating this standard into the Rules and changing the formula for calculating one load - the vertical bending moment –it made absolute sense to review the formulations for all loads in the Rules.

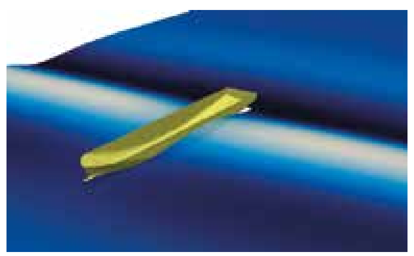
Revisiting the North Atlantic assumption

The starting point for the work on the new Rules was their existing basis – namely that the requirements they contained for ship structures were based on the loads and stresses imposed by North Atlantic wave conditions over an operating life of 25 years. Ships have traditionally been classed on this assumption of North Atlantic routes, as they are home to the most extreme sea states and are commonly used.

The team set about the work by computing hydrodynamic loads and their corresponding movements (shear forces, bending moments, accelerations, etc.) for a database of 74 ships – all of different types, draughts, lengths, beams and block coefficients, but crucially including 21 Containerships. Combining the results with North Atlantic sea-state data in the form of scatter diagrams revealed the extreme loads that would occur for a ship operating 25-years on this route.

All the hydrodynamic computations were carried out using HydroSTAR®, Bureau Veritas' hydrodynamic software developed over the last 30 years.





Accurate load case selection requires simulating different headings to obtain accurate dominant loads.

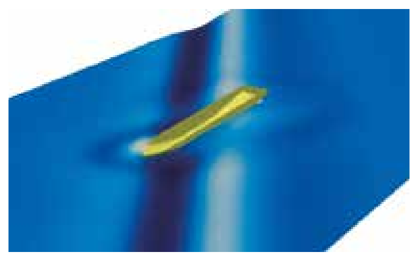
Basing the Rules on real-seas – finding the equivalent design wave

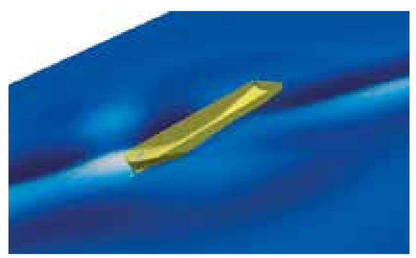
These first computations led to rule formulations that defined the maximum value for each type of load, but in reality, different loads do not occur at their maximum value at the same time. For example, the maximum vertical bending moment does not occur at the same time as the maximum horizontal shear force or the maximum pitch acceleration.

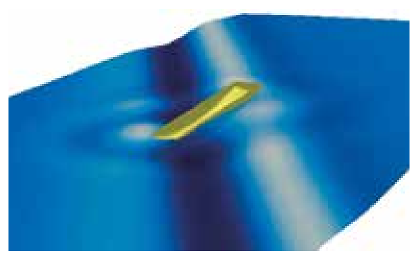
Applying all the loads simultaneously at their maximum value in the Rules would be unrealistic and overly conservative.

Bureau Veritas needed to combine the loads in a realistic manner to make the Rule requirements as accurate as possible –in essence to reflect the real behavior of seas.

This is where the design waves came in, providing the key to defining realistic load combinations.







The Bureau Veritas team wanted to make sure loads used in the Rules were consistent with this North Atlantic assumption, and crucially to pinpoint the realistic sea states that would result in the most extreme loads – those that when applied in the Rules would determine the safest possible structure for a ship. Put another way, they wanted to identify the 'worst' of the roughly 100 million waves that a ship would encounter in its 25 years at sea.

For each type of load, the team selected an equivalent 'design wave' that would produce the most extreme load, i.e., producing this specific load at its maximum value of 100%, but crucially also producing other load effects, all at lesser values. Ultimately, the Bureau Veritas team chose seven design waves.

To test the accuracy of the design wave loads, intensive hydro-structural computations were carried out on four ships, to calculate their structural response to these seven design waves. The same hydro-structural computations were also carried out to calculate the ships' response to the 25-year North Atlantic wave data provided by the earlier scatter diagrams.

The computations were carried out using Homer, hydro-structural software developed by Bureau Veritas over the last 10 years. Homer couples the hydrodynamic loads computed by HydroSTAR® with a commercial Finite Element solver (such as Nastran) to compute the structural response of ships to all types of waves.

The results showed that the maximum structural response to the seven design waves was nearly equal to the maximum response across the 100 million waves faced by a ship over 25 years of North Atlantic operations, for all the structural parts of the ship.

Finally, the design waves had to be translated into the formulae for calculating extreme loads that underpin the new Rules. This involved going back to the database of 74 ships and computing the design wave loads for each one, each design wave being described in terms of the values for each load being applied, with one load effect maximized, and the other loads described as a percentage of this maximum value, known as a load combination factor (LCF). These values have translated into the new Rule formulations.

5 design waves were also selected for fatigue loads.

Basing the Rules on real seas

Following the lead of academic hydrodynamics research, the 'design waves' are irregular waves, meaning that they are a much more realistic representation of actual sea conditions. Quentin Derbanne, Head of Research for Bureau Veritas's Marine and Offshore Division, explains: "To date, Rules and industry guidance have been based on regular, sinusoidal waves, like the ones that you might see in a child's drawing. You would never see a sinusoidal wave at sea, so it made sense to base the Rules on real, irregular seas."

The results

With a much bigger database of ships, and with today's vastly superior computational power both in terms of quality and the number of computations that can be performed, the results of the work to revise the Rules give a higher degree of certainty than ever before.

The loads that are now applied to ship structures by the Bureau Veritas Rules are more accurate and reflect real sea states. Among the changes, vertical bending loads are in line with URS11A, with a consequent shear force increase, other loads have been derived in a fully consistent manner, and pressure on the ship's hull has been described more realistically, leading to a reduction in pressure on the ship's bottom.

However, the really significant result is that, overall, accelerations have been reduced. This has key beneficial consequences for containership operators, giving them greater operational flexibility.

The equivalent design wave explained

A ship will meet about 100 million waves during its 25-year life, all exerting different loads, depending on their height, shape and behavior. The ship responds to these different 'sea loads' with a range of movements and structural deformations. But what kind of waves will produce the most extreme loads and movements? And therefore, which ones are the most critical in determining the safest possible structure for the ship? This is what the Bureau Veritas team identified. They are 'equivalent design waves' – and they now underpin the new Rules for containerships. Crucially, the design waves reflect the real and irregular behavior of seas, applying a realistic combination of load effects to give greater accuracy than ever before.

Measurements that validate the tools

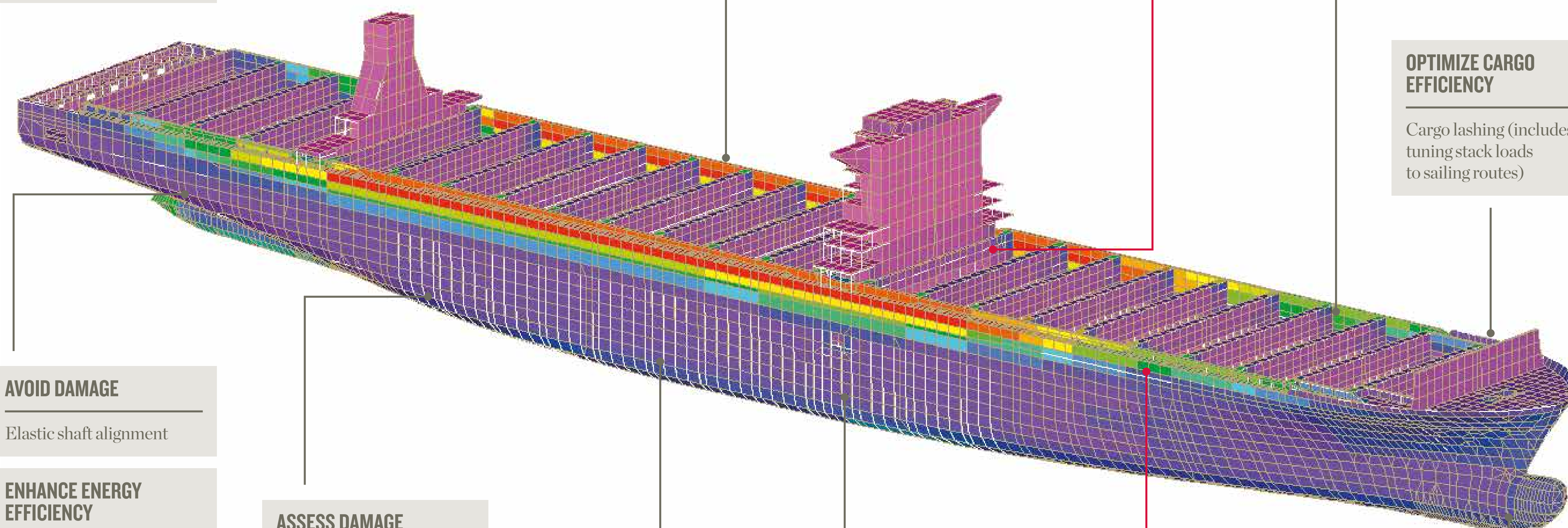
Two CMA-CGM Containerships are now instrumented to measure the actual sea loads they are encountering. Although these ships are not encountering the full range of sea conditions, the onboard measurements they are capturing are being compared with the design wave loads, validating the computational tools that have been used.

PARTNER OF CHOICE

FOR SAFETY AND PERFORMANCE

Vasilis Gkikas,
Global Market Leader
Containerships & Bulks

Bureau Veritas offers a wide range of services to safeguard your crew, vessel and equipment, and to improve efficiency and performance.



BE PREPARED FOR THE UNEXPECTED
Emergency response services

REDUCE RISK
Classification

DEMONSTRATE COMPLIANCE
Statutory certification

IMPROVE SAFETY AND COMFORT
Global vibration analysis

SAFEGUARD AGAINST EXTREME WAVE MOTIONS
Parametric and dynamic roll analysis
Wave detection and warning

ENHANCE REEFER CAPACITY
SEECAT, our tool for ship efficiency calculation and analysis

OPTIMIZE CARGO EFFICIENCY
Cargo lashing (includes tuning stack loads to sailing routes)

AVOID DAMAGE
Elastic shaft alignment

ENHANCE ENERGY EFFICIENCY
ESD* evaluation

IMPROVE PERFORMANCE
Propeller & appendages optimization

ASSESS DAMAGE
Complete ship FEA** & spectral fatigue

OPTIMIZE FUEL USE
Gas fuel services

GET READY FOR THE FUTURE
Gas prepared notation

SAFEGUARD SHIP INTEGRITY
Whipping & springing services

BOOST PERFORMANCE
Hull form optimization

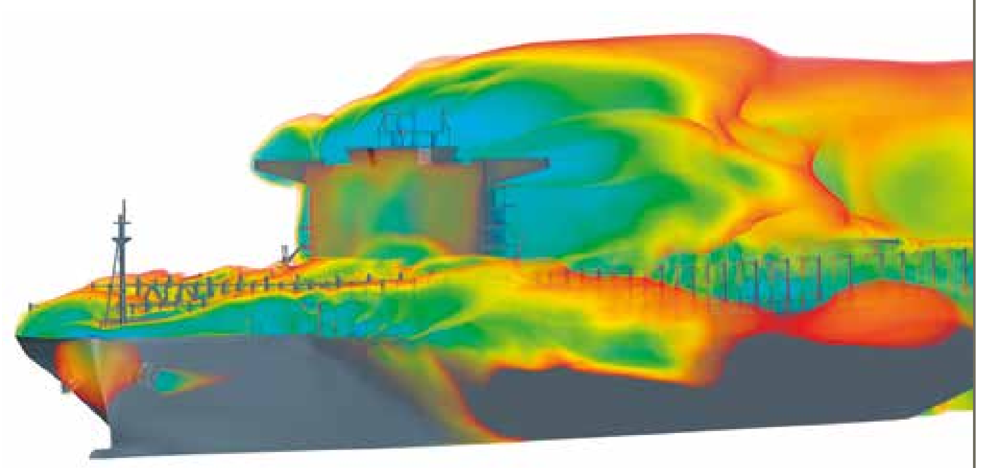
*ESD: Energy Saving Device **FEA: Finite Elements Analysis

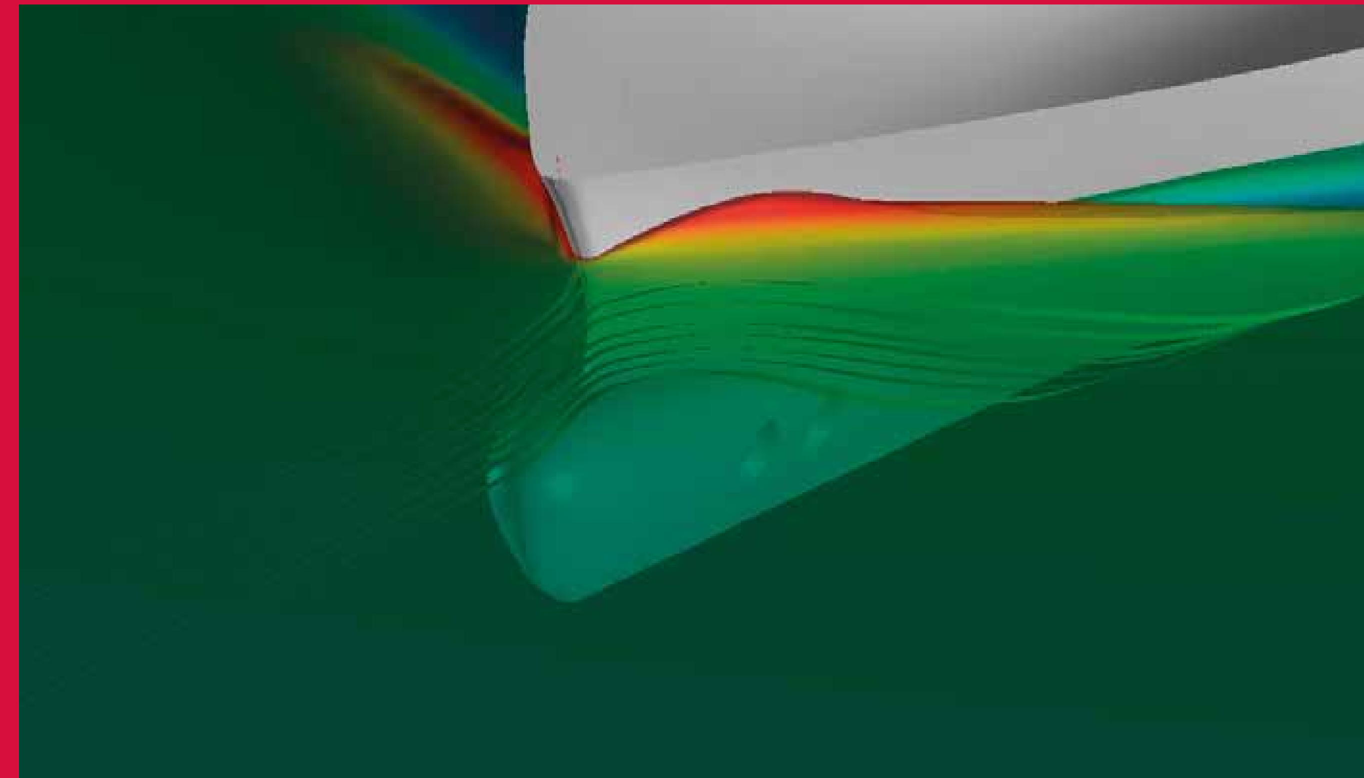
SUPPORTING CONTAINERSHIP PERFORMANCE

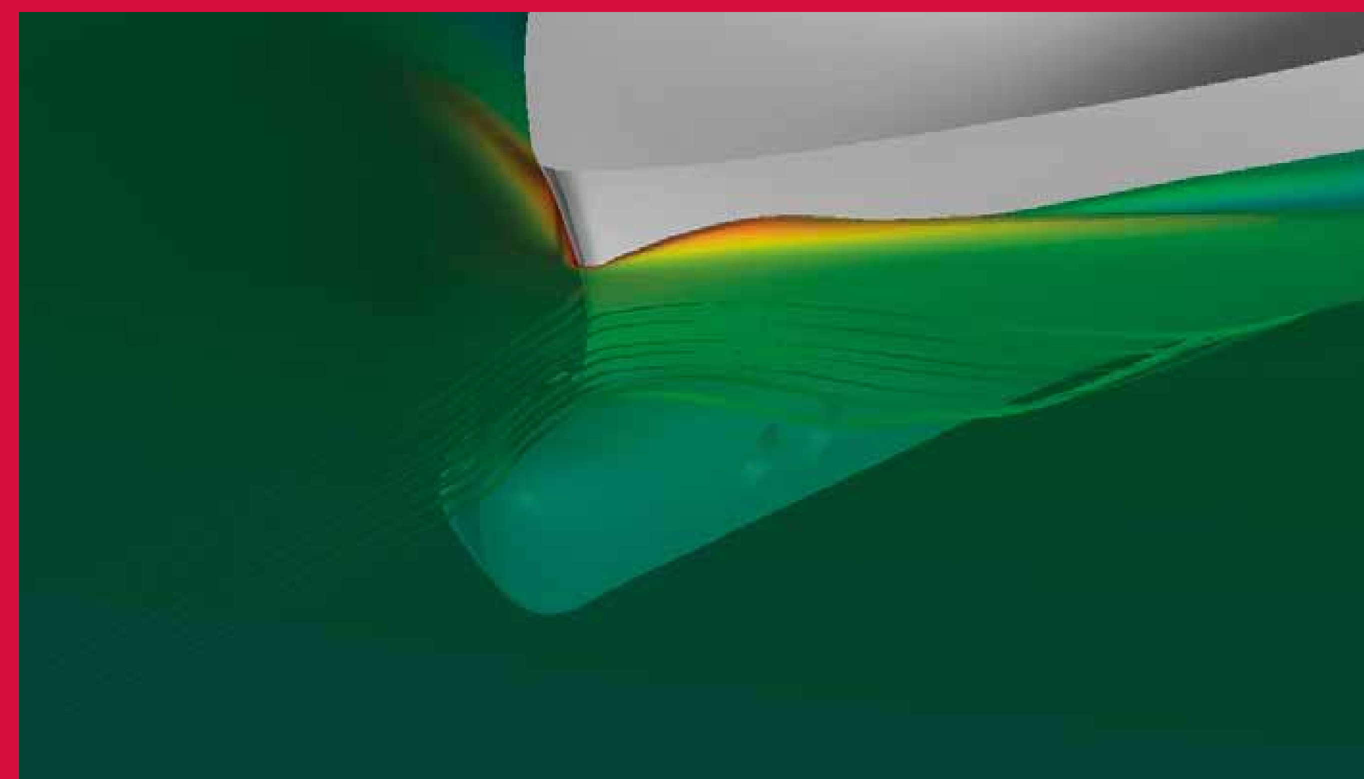
Bureau Veritas' Marine & Offshore Services Department delivers engineering, risk and supervision services to ship-owners and shipyards through subsidiaries Tecnitas (Structures) and HydrOcean (Hydrodynamics).
Building on experience in the containership market, strong partnerships with clients have been developed, especially with CMA-CGM, who have retrofitted dozens of their containership supported by HydrOcean's bulbous bow optimization studies. This has reduced fuel consumption by 5-10%.
The HydrOcean team has now performed over 75 containership bulbous bow, propeller and full hull optimizations and regularly collaborates with ship owners and designers on new construction projects and in-service vessels.

HydrOcean key strengths:

- Experience and number of validations performed.
- Use of fast and accurate RANSE-CFD programs with many licences for parallel evaluation of numerous hull or appendage designs. HydrOcean has access to an unlimited number of CFD program licences co-developed with the Ecole Centrale de Nantes.
- Most shipyards and competitors still rely on potential flow programs that are not adapted for these simulations or can run very few CFD calculations.
- Use of dedicated hull and appendage parametric modelling software linked with CFD programs. HydrOcean has developed its own unique modelling tool, OptNav.
- Availability of huge CPU power, enabling short restitution time of computations and respect of schedule, plus access to a 6,000 core cluster.







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