1,750-ton deadweight-capacity (dwt) chemical tanker designed by Delta Marine Engineering

Designing Safe and Reliable Ships

Delta Marine Engineering uses up-front simulation to design ships that are more comfortable and last longer.

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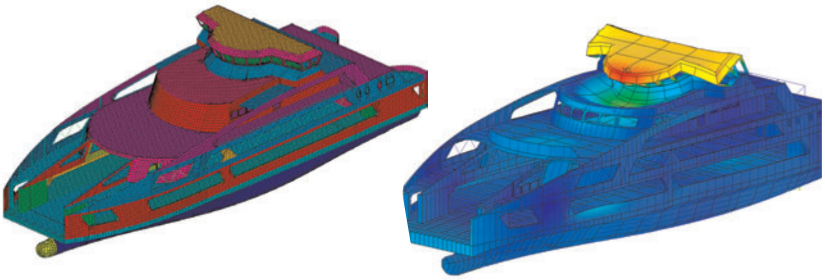
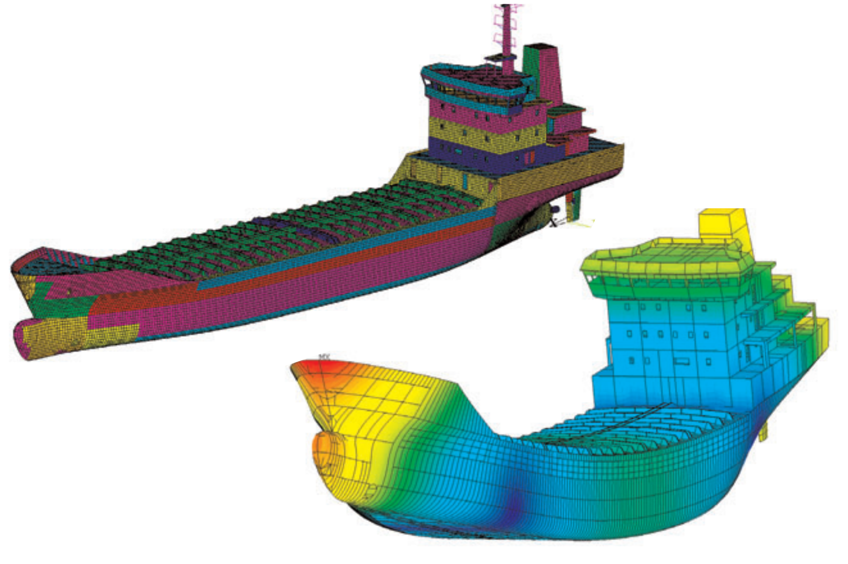
Ocean-going merchant ships are continually slammed, not just by shifting natural forces but also by loads, such as forces generated by the propellers and engine. These forces have the potential to generate vibrations that can make life miserable for the crew and, over time, damage the ship. The challenge for marine engineers at Delta Marine Engineering Co. — an engineering and consultancy services provider for the design of various types of ships, including general cargo ships, container ships, oil and chemical tankers, passenger ships, ferries, yachts, and navy ships — is to design a ship to keep structural vibrations to low levels in order to ensure the comfort of the crew and a long vessel life. This design challenge requires a solid understanding of the structural behavior of the ship and its interaction with the surrounding water.

Complex fluid and structural interactions govern the performance of a ship, so Delta Marine uses ANSYS Mechanical structural mechanics software and ANSYS FLUENT fluid dynamics software early in the design process to understand the intricacies. Engineers can identify vibration and other problems early on and make changes, such as altering a propeller design, to get the design right the first time. This avoids the need for expensive changes that could run into millions of dollars if the problem is not discovered until after the ship is launched. Each ship presents unique engineering challenges, so the company performs advanced engineering analyses for every single new design it creates, which enables Delta Marine to build safe and reliable designs and to efficiently apply the concepts to customers' sister ships.



Mesh (left) and superstructure vibration mode (right) of a 48-car capacity ferryboat.

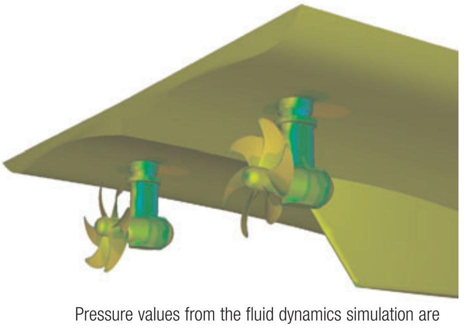
The primary forces acting upon a ship in normal operation are generated by the propeller and engine. The main engine in a 300-meter bulk carrier ship is a two-stroke low-RPM engine that weighs about 550 tons and operates at 1.5 Hz. The propeller also runs at 1.5 Hz. One of the most basic tasks that marine engineers face is preventing resonance in the structure. As the propeller moves the water, it exerts forces on the back of the ship, and these forces are large enough that they can cause vibration, particularly if they excite one of the structure's natural modes.



4,750-dwt chemical tanker mesh density (left) and 7,500-dwt chemical tanker first bending vibration mode (right)

Fluid Flow Simulation Generates Propeller Forces

As each propeller blade moves through the water, it is exposed to many different flow regions, resulting in propeller thrust variations as well as variations in the reaction forces exerted on the propeller shaft. Delta Marine engineers use ANSYS FLUENT software to calculate pressures induced by the propeller on the aft of the ship as well as the loads generated on the propeller shaft. The engineering team performs these simulations with the propeller rotating. The solution is transient and the propeller zone is simulated with the sliding mesh model. The propeller turns one degree at each time step, and the analysis finishes after at least one revolution. The fluid dynamics investigation provides pressure values that Delta Marine engineers convert to forces.



Pressure values from the fluid dynamics simulation are converted to forces and used in vibration analyses. Contours of static pressure are shown.

Structural Mechanics Determines Vibrational Deflections and Velocities

Delta Marine engineers also produce a finite element model of the ship and perform vibration analysis to identify the major mode shapes and frequencies. The analysis team exports the ship design from in-house marine engineering software into the ANSYS Mechanical product. Delta Marine has developed a special software package, called Deltaflow, which accounts for the effect of water on the structure. This software solves the potential flow around the hull, determines streamlines and calculates the resistance of moving the ship through the water. The technology also identifies mass values that are added to the underwater structure to account for the effects of the water.

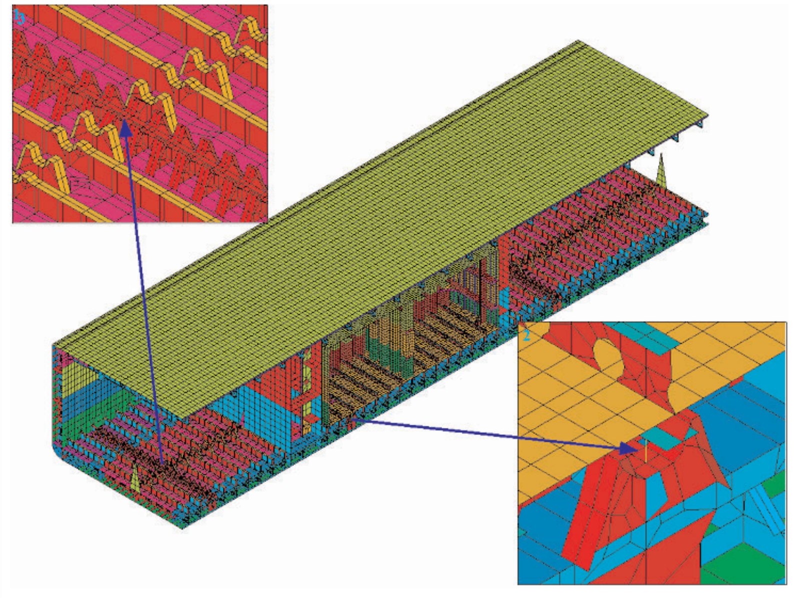
Next, engineers apply the static forces (determined via fluid dynamics simulation) to the finite element model to calculate the forced-vibration displacements and velocities. These values are then compared to the ISO 6954:2000 standard: "Mechanical vibration — Guidelines for the measurement, reporting and evaluation of vibration with regard to habitability on passenger and merchant ships." In forced-vibration analysis, ANSYS Mechanical software applies the periodic forces identified using fluid dynamics to the model and determines the vibrational displacements and velocities. Typically, it takes Delta Marine engineers between four and six months to create a detailed finite element model of a ship. Then it takes one day to perform modal analysis and another day to perform forced-vibration analysis.

If vibration levels are higher than the ISO standards, then the commissioner or owner will not accept the ship until expensive changes have been made. By identifying vibration problems early in the design process, Delta Marine makes alterations such as adding pillars, strengthening structural components, or changing the propeller, revolutions per minute of the crankshaft or number of blades in the propeller. Then, engineers update the model to determine the effect of the changes on vibration displacement and velocity. Once a ship has been built, possible changes become not only much more limited but more expensive as well. For example, changing the underwater form of a ship in the design stage can be done at almost zero cost, while making changes after it has been constructed costs millions for a large ship — and it is impractical.

Because the main engine and propellers take about a year each to be supplied, they are ordered and under construction before analysis is performed — and changes to these components, at that stage, are difficult and expensive to make. As a result, Delta Marine engineers try to correct any problems by modifying the structure of the ship. Engineers typically evaluate three or four modified structural designs to determine their vibrational characteristics, which, in the end, results in optimum vibrational response.

Structural Analyses of Tankers

Delta Marine also uses ANSYS Mechanical technology to evaluate the structure and cargo tanks of ships against hydrostatic and hydrodynamic worst-case load scenarios involving forces exerted by the contents of the tank against the tank. For example, the design and construction of sulfur and bitumen-carrying tankers is complicated by complexity of the cargo tanks, which could be built either independently or as part of an integrated structure. The cargo is carried at temperatures up to 250 degrees Celsius in order to maintain relatively high viscosity. If an integrated tank scheme is used, there could be high stresses in the tank structure due to differences between the temperature of the sea and the temperature of the cargo. These stress concentrations can usually be corrected by making structural modifications. In the case of an independent tank configuration, thermally induced stresses and deflections in the main structural components must be avoided.

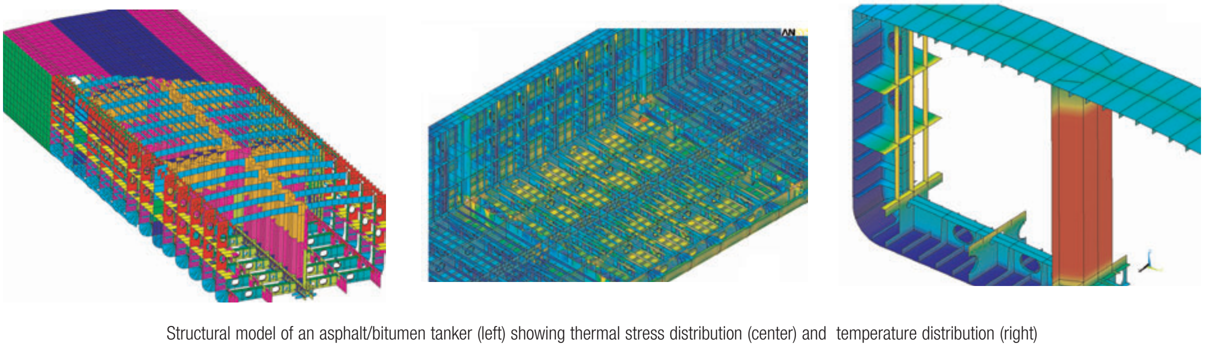


Main construction of a sulfur tanker with separated internal cargo tank

Delta Marine engineers typically investigate the structural durability of the amidships cargo construction and internal cargo tanks of bitumen- and sulfur-carrying tankers by analyzing the model in three steps.

1. A thermal analysis is obtained by applying the temperature boundary conditions and film coefficients that were obtained from experimental tests. Thermal analysis provides the final temperature distribution along the structure according to heat transfer laws.
2. The temperature distribution along the structure, obtained from thermal analysis, is applied to the structural analysis model as loads, and resulting thermal stress values are obtained. These values are very helpful in designing the main structural construction. As a result, the midship structure is ensured to be safe in relation to thermal stresses.
3. The main structure of the ship is analyzed under thermal loading, and local hydrostatic or hydrodynamic pressure loading is analyzed by considering the global bending moments and shear forces. Therefore, the response of the construction under both global and local loading is investigated and optimized.

Delta Marine engineers use both structural mechanics and fluid dynamics simulation technologies from ANSYS to accurately predict some of the most difficult marine engineering problems. Simulation provides them with the ability to accurately determine the performance of design concepts, reducing the need for physical testing for fluid dynamics applications. Using engineering simulation makes it possible to evaluate many more designs, resulting in a substantial improvement in performance. At the same time, the lower cost and shorter lead times for simulation provide faster time to market and reduced development costs. ■



Structural model of an asphalt/bitumen tanker (left) showing thermal stress distribution (center) and temperature distribution (right)