Around-the-World Ocean Racing

Farr Yacht Design gets help from analysis software to meet the rigors of racing on the Disney-backed Pirates of the Carribean racing yacht.

Left: Farr Yacht Design has provided the design and engineering for many winning Volvo Ocean Race contenders over the past 25 years. The Disney-backed "Pirates of the Caribbean" shown, placed second in the 2005-2006 edition of the race. The grueling 9-month, round the world event covers some of the most extreme and inhospitable sailing conditions on earth, including winds up to 60 knots and ocean swells up to 30 feet high, with the boats capable of speeds in excess of 40 knots. **Right:** NEi Nastran Finite Element Analysis (FEA) software from Noran Engineering is used to simulate the performance of the entire yacht made from carbon fiber composites. Images shown are displacement contour plots for an extreme condition of impact with a submerged object.

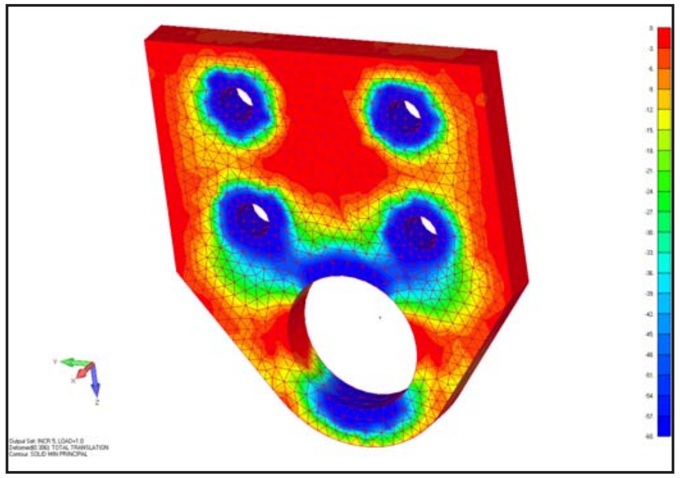
Farr Yacht Design (FYD) uses NEi Nastran to enhance its structural analysis and simulation for its line of yachts. FYD is a leader in the design and engineering of high performance racing yachts for major events including the America's Cup and the Volvo Ocean Race, as well as custom and production yachts for builders around the globe.

"Structural analysis is an increasingly important component of successful racing yacht design", comments Dave Fornaro, FYD design engineer. "We have been utilizing FEA for several years to validate and improve our designs and desired to enhance our suite of analysis tools with more advanced capabilities in several areas including laminated composites, non-linear surface contact with friction, and bolted joints with pre-load. After an exhaustive review, NEi Nastran stood out as the best choice based on its advanced capabilities, cost-effectiveness, and quality technical support."

FYD's first application of Nastran is for it's next-generation of designs for the Volvo Ocean Race, a grueling round-the-world race sailed in fully crewed, 70-foot carbon fiber yachts capable of speeds in excess of 40 knots. "These designs are forging new frontiers in ocean racing," adds Dave Fornaro. "They operate in harsh and brutal conditions and require a rigorous level of structural design and analysis to ensure peak performance and safety."

Two Phases of Analysis

A typical analysis for a racing yacht is split into two phases: global and detailed. In the global analysis phase, FYD models the entire hull, deck and internal structure as laminated composite shell elements. A typical model will contain approximately 125,000 elements. The



This detail shows the minimum principal strains for a metal bracket with bolt preload and contact surfaces.

composite materials are orthotropic in nature—that is they have different mechanical properties in different directions. This adds an extra layer of complexity as compared to isotropic materials such as metals.

According to Dave, "NEi Nastran has excellent capabilities for modeling laminated composite materials. We use spreadsheets to calculate the properties for individual plies and laminates (collections of plies) based on classical laminate theory. We have developed an automated method for transferring this data from the spreadsheets directly into NEi Nastran such that all ply and laminate definitions are read in with the correct naming and formatting of all mechanical properties. These properties are then applied to the appropriate areas of the model."

Global models can contain as many as 150 different laminates, each with three plies representing two skins on either side of a core material. Several load cases are then run representing various typical sailing conditions as well as extreme load cases such as grounding or slamming in waves. These load cases are then post-processed in NEi Nastran and the results compared to criteria for global strains and deflections. This information can then be used to update the laminates as needed and re-run the analyses in an iterative fashion until all areas of the design meet the requirements.

"In the detailed analysis phase," David said, "we look more closely at critical areas of the yacht that experience large strains." Such areas are often at the junction of major structural elements such as canting keel pivot pins mounted into transverse bulkheads. For these detailed models, FYD's design team will often remove a portion of the global model complete with enforced boundary conditions from a particular load case to use as the starting point. "We will then modify the models as required to study the areas of interest in more detail. Typically we will use a combination of solid and shell elements," David said.

The solid elements are required in areas where transverse strains need to be calculated, or at contacting surfaces such as pin joints where through-thickness effects need to be captured. NEi Nastran has particularly good capabilities for modeling and analyzing contacting surfaces so as to accurately study pressure distributions and strains across the interface between the components. "This is very helpful for studying effects such as the distribution of loads among the fasteners in a bolted joint, including the effects of clamping and friction due to bolt pre-load," David said.

Through the combination of global and detailed analyses, FYD is able to engineer their yachts to a much higher degree of fidelity than would be possible using traditional engineering methods alone. However, traditional engineering methods are still a very necessary part of the job, both for initial design work as well as for a check on the FEA results.

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