Getting the Mast from **Virtual Prototyping**

Structural simulation tools help optimize main mast weight to increase megayacht sailing performance.

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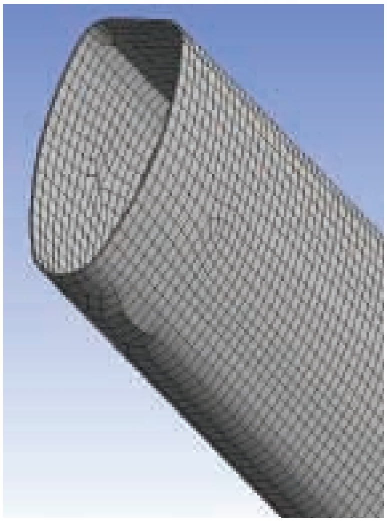
Sailing yacht developed by Perini Navi

A cross section of the mast



Shell model used in analysis of local buckling phenomena

In the extremely selective large sailboat market, Perini Navi sailing yachts have long been acknowledged for their high performance in terms of balance, speed, reliability and safety, as well as their aesthetic details and passenger comfort. With 42 yachts launched around the world since 1983 and many more under construction at its shipyards in Italy and Turkey, Perini Navi now meets more than half of the global demand for sailing yachts greater than 50 meters in length — the so-called megayachts. To meet the growing requirements of its customers, Perini Navi has found it necessary to combine the distinguishing and well-consolidated features of its yachts with constant improvement in technical solutions over a wide range of conditions.

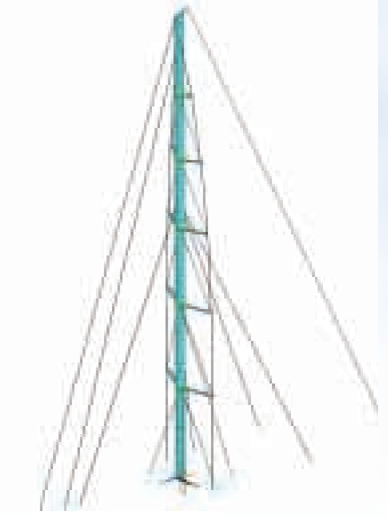
In this context, Perini Navi developed a pilot project to take advantage of automatic optimization techniques based on virtual prototyping. The project was born out of Perini Navi's collaboration with EnginSoft of Florence, Italy, and was concerned with the optimization of the main mast structure for a special series of new heavy cruiser motorsailers ranging in length from 50 to 60 meters (164 to 197 feet). The goal of this effort was to identify the solution best able to minimize the mast's weight while maximizing strength to avoid specific global and local buckling factors. Accurate modeling using structural simulation offered the possibility of not only a weight reduction of the mast structure but also a large balancing reduction in keel weight, thus increasing the overall sailing performance of the boat. Other important factors that stimulated the project included the potential cost savings associated with using less aluminum for the mast and lead alloys for the keel, an easier product construction due to a reduction in the weight and thickness of the mast plates, greater sailing comfort resulting from the reduction in the boat's tilting, and overall shorter time to market.

The mast design methodology consisted of first analyzing the global buckling factors on the transverse and longitudinal planes. Starting with models developed by Perini Navi in ANSYS Mechanical software for structural simulation, EnginSoft analysts parameterized the models using the

ANSYS DesignModeler application within the ANSYS Workbench platform. They then analyzed three different models of the entire mast structure — including the mast panels and cross-trees, cable shrouds and stays — with ANSYS Mechanical software.

The first model consisted of a simplified section of the mast and included the cross-sectional area and relative moments of inertia as parameters. The range of values for these parameters, resulting from varying the mast geometry, were then used in the second model, which consisted of the entire mast structure; this model was used to analyze the global buckling of the mast. Since the structure was hyperstatic, or over-constrained, the solution depended on the constitutive equations. Thus, the global buckling model took into account the nonlinearities resulting from high deformations of the mast during the initial preloading stage in which the load is the result of the cable shrouds tightening. This model also allowed the structural coupling between the longitudinal and transverse planes. Finally, to analyze local buckling phenomena, a third model — a shell model of the mast section — was created. To carry out the analysis of both global and local buckling, the preloading of the shrouds was taken into account, first by a preliminary static analysis, then by a linear buckling analysis.

EnginSoft engineers developed the procedures to integrate the three ANSYS structural models with the associated optimization process using the modeFRONTIER™ multi-objective optimization software platform from ESTECO. Using modeFRONTIER, the analysts automatically processed the same geometric parameter variables that mast designers would normally be responsible for based on their experience.

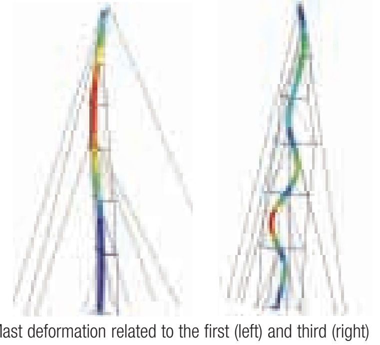


Global buckling model of the mast in ANSYS Mechanical software

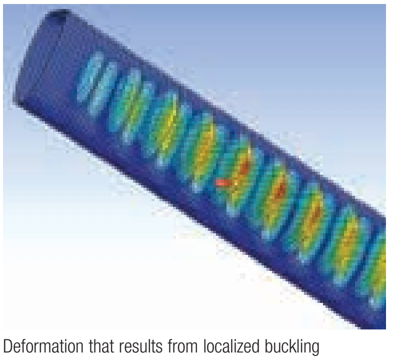
The mast of the sailing yacht

This integration process had an impact on Perini Navi's previous design methodology because it imposed a set of parameters under strict requirements; however, the process was able to exploit the entire potential of software from ANSYS through the ANSYS Workbench interface. The ANSYS Workbench environment allowed for the robust regeneration of the numerical model according to the variation of the input parameters, the automatic application of boundary conditions, the automatic recognition of connections between the cable shrouds and mast, and the ability to carry out advanced visualization and reporting using pre-processing and post-processing features.

The results of virtual prototyping, achieved in terms of both effective weight reduction of the mast and savings of time and materials during machining, led to a decision by Perini Navi to widen its ANSYS Workbench applications to other design protocols, such as the verification of welded joints. The advantages to Perini Navi were notable, as EnginSoft engineers were able to reduce the mast weight by 3 to 5 tons, or approximately 20 to 25 percent. They also could then apply the structural model within the ANSYS Workbench environment to different masts for other boats. Furthermore, the model can now be detailed and adjusted to different load configurations, such as open sail or heeling, to benefit both the efficiency of the development process and the reliability of the final product. ■



Mast deformation related to the first (left) and third (right) buckling factors for the global structure



Deformation that results from localized buckling in the mast