COSTUMER STORY // PROCESS ENGINEERING

OPTIMIZATION OF FIBER COMPOSITE COMPONENTS IN YACHT RACING

Apart from ANSYS Composite PrepPost, ar engineers used optiSLang in the design phase for an advanced optimization of the boom of a sailing race dinghy.

For decades, fiber composites have been successfully applied in yacht racing. The knowledge of application has reached an incredibly advanced level. Especially for construction parts with just a few requirements regarding the boat design, the technical development supported by simulation software is an important factor for success.

Sailing and construction teams consider further technical optimization as an economic challenge, especially in the highly developed boat classes. Low production quantities even increase the cost pressure on development asking for special approaches of design.

Less weight, but the same strength and rigidity

The boom of a racing dinghy serves for hoisting and trimming the main sail. It takes up a significant part of the sailing force. Thus, strength and rigidity properties of the boom are of crucial importance for the sailing performance. At the same time, the boom needs to be as light as possible to meet the requirements of competitive racing. As boundary conditions for the optimization, the load cases and the design space of the boom were predefined. In addition, the solution should ensure the reutilization of existing molding tools. This eventually restricted the focus of optimization potential to the multi-layer laminate. The aim was a significant weight reduction of the boom while keeping its properties regarding strength and stiffness unchanged. Eventually, the team focused on four key parameters to improve the properties of the fiber composite laminate: the layer angle, the layer number and arrangement, as well as the selection of materials. The reduction of theoretically possible parameter combinations to the practically meaningful ones regarding manufacturability and material availability accelerated the actual optimization process.

Simulation tools for composite structures

The construction team of ar engineers designed the fiber composite components with the assistance of the software ANSYS Composite PrepPost, which is fully integrated in the simulation environment ANSYS Workbench. The tool is especially capable for design development and considers the modeling of structures and the draping. In addition, the software provides a compact display of results based on combined failure criteria. With the software optiSLang inside ANSYS, the optimization procedure can be conducted without leaving ANSYS Workbench. This guarantees a data transfer without connecting problems. The uniform and user-friendly interface also resulted in an overall shorter processing time. A parameterized FEM model functioned as a basis for optimization with the parameter set generated by optiSLang and controlled by ANSYS Workbench.

The application of optiSLang was performed in three steps:

- Sensitivity analysis
- Optimization
- Robustness evaluation

In the first step, the sensitivity analysis, the design or input parameters and the result values or output parameters were defined and classified within a value range (10% standard). Based on these parameters, optiSLang then generated a design of experiment including various combinations of parameter values. After simulating the individual design variants, optiSLang created a surrogate model for the result visualization of the sensitivity analysis using different types of graphical post processing. The evaluation of the results illustrated the correlations between the individual parameters as a significant contribution to the understanding of the function and component behavior. This represented the basis for a target-oriented optimization.

Optimization with subsequent validation

In the following step, the procedure of optimization differed depending on the significance of the surrogate model. A high prognosis coefficient indicates the possibility to conduct an optimization just by using the surrogate model and a subsequent validation through the FEM model. This time saving procedure is therefore preferable. In the case of having a surrogate model with low prognosis quality, possible causing effects should firstly be investigated. The recalculation of certain design points or changing input parameters can already help to improve the coefficient of prognosis.

A minimization of weight as the main goal of the boom optimization was configured in optiSLang. The team of ar engineers considered safety limits at various points of the boom as constraints. In addition, the deflection was not allowed to exceed the limit. Due to the carefully prepared optimization, the surrogate model showed a high accuracy capable of running a direct simulation. The procedure of optimization, the validation with the FEM model as well as further parameter adjustments finally achieved a weight reduction of 18%. At the same time, the mechanical properties of the boom remained unchanged or were even improved in several cases.

Since some design input parameters, like layer angles, have typically been subjected to production-related scatter, the consideration of this influence by conducting a robustness analysis is also of great importance. Combined with the knowledge of the underlying stochastic process, optiSLang allows a classification of distribution and, thus, the determination of the reliability of the individual design values.

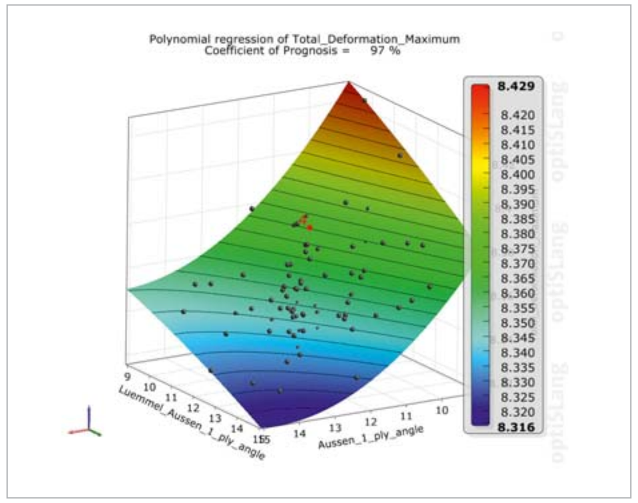
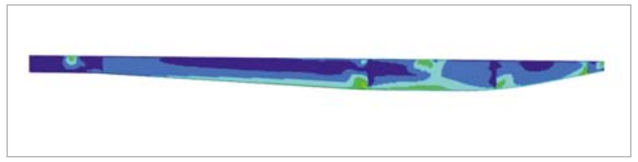


Illustration of evaluation results in optiSLang

Especially while exploring the performance limits of a component, as it is often the case in yacht racing, the results of a robustness analysis provide several advantages. A proven robust design guarantees an increased safety against random scatter of input parameters. Thus, the individual components can already be optimized during the design phase according to the extreme demands in later use.



Puck failure criteria

ar engineers has performed an optimization that resulted in a boom that is lighter and even more rigid than the previous model while also fulfilling the predefined safety margins for the material. A better utilization of the safety margins in all fields could further improve the weight reduction potential of the component. At the same time, an effective product development process could be determined by combining the optimization software optiSLang inside ANSYS with the practical know how in the design of components made of fiber composite materials. The results of this application will also serve as a basis for future component optimizations and feasibility studies.

Author // Axel Reinsch (ar engineers GmbH)
axel.reinsch@ar-engineers.de | www.ar-engineers.de