CASE STUDY // CONSUMER GOODS INDUSTRY

DIVERSITY OF VARIATIONS IN VIRTUAL PROTOTYPING OF TENNIS RACKETS

Robustness evaluation and optimization of HEAD tennis rackets with multiple input and objective parameters using optiSLang® and ANSYS®.

Optimization task

When HEAD engineers first began using simulation, they evaluated a single design iteration, made changes based on the results, and ran a new simulation. It took approximately one week to evaluate the performance of each iteration. The process of design optimization of tennis rackets considers various input parameters. Different fibers, FAWs (Fiber Area Weight), angles and different component compounds and placements yield a large number of possible variations. In addition, a sufficient amount of optimization variables and objective parameters (e.g. stiffness, strength, impact behavior, production costs) are taken into the consideration. This can result in up to 20 million combinations. If one were supposed to build and test a prototype per day, it would take 2750 years for 1 million combinations! By conventional means, in real prototyping, such a computational effort for a sufficient number of designs and quality evaluation can not be realized. The optimization potential remains unused to a large extent.

Methods of solution

Today, HEAD engineers frequently use Dynardo`s optiSLang as a nonlinear optimizer to generate design iterations and run ANSYS Mechanical simulations automatically in a batch process to identify the optimal solution. Thus, engineers evaluate approximately 1 million design concepts in about a week to improve the design of a composite structure.

The typical goal of an optimization is to find the lightest structure with the highest stiffness and strength that meets other design constraints. Using optiSLang, large amounts of multidisciplinary non-linear optimization variables (layer thickness, angle, material ...) can be considered and evaluated with different priorities (weight, balance ...). The parameterization of layout and geometry is realized in ANSYS. Running a sensitivity analysis, optiSLang identifies the relevant input and output parameters, quantifies the forecast quality with the help of the Coefficient of Prognosis (CoP) and chooses the best Metamodel of Optimal Prognosis (MOP). Based on this identification, the number of design variables are decisively reduced and an efficient optimization can be performed. Thus, a robustness proof of the optimal design as well as the avoidance of over-engineering reliability goals become an integrated part of the optimization procedure. The meta-model is used for global optimization in order to determine, depending on the desired objective functions and constraints (e.g. scattering material values), the "optimal" design for "real prototyping". Based on the determined design improvements using global meta-models, further optimization steps can be conducted. For this purpose, optiSLang provides a variety of algorithms. These include, among others, classical gradient-based algorithms, adaptive response surface methods or nature-inspired optimization methods such as evolutionary strategies or genetic algorithms.

Costumer's benefit

The ability of prognosis is the key to efficiency. Thus, a "no run too much"-philosophy can be implemented minimizing solver runs. Additionally, the evaluation of prognosis allows to distinguish between physical and numerical effects on the change of output variables. For example, it is possible to quantify the influence of meshing if geometry changes. If permissible limits are violated by scattering output variables, optiSLang identifies safely (statistically provable) the responsible scattering input parameters. The design optimization of the racket does not have to be limited to a few parameter (CAE + CAD) any longer. The full optimization potential can be explored. Furthermore, oversizing is minimized by the implementation of specific variations. The ability to identified automatically the most important parameters made it possible to analyze such a large number of design alternatives and to optimize performance to a level that would never have been possible in the past.

With the help of optiSLang, design concepts have been frequently identified that are such a departure from traditional engineering practices that the team would never have thought them applicable. HEAD has developed a challenging series of quality tests that measure stiffness and strength, which every racket must pass before entering the market. For example, the racket must withstand a drop test onto concrete without any damage.

The combination of optiSLang's stochastic and optimization algorithms with the parameterization and preprocessing capabilities of ANSYS Workbench enable engineers to quickly and easily evaluate each proposed design from a quality standpoint, all from the early stages of the product development process. Simulation and Robust Design Optimization (RDO) have played a significant role in the dramatic improvements that HEAD has achieved in the performance and durability of its tennis rackets. The detailed and accurate design information provided by optiSLang and ANSYS combined with the experience of HEAD engineers has made it possible to produce extremely lightweight designs that can withstand the enormous forces generated by string tension as well as the impact of the ball on the racket during the serve.

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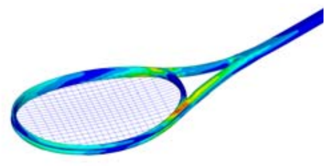
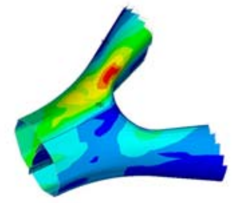
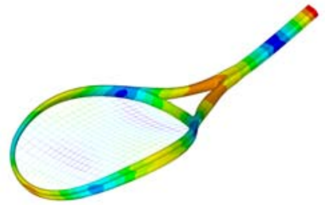


First bending mode of a strung tennis racket in tension.

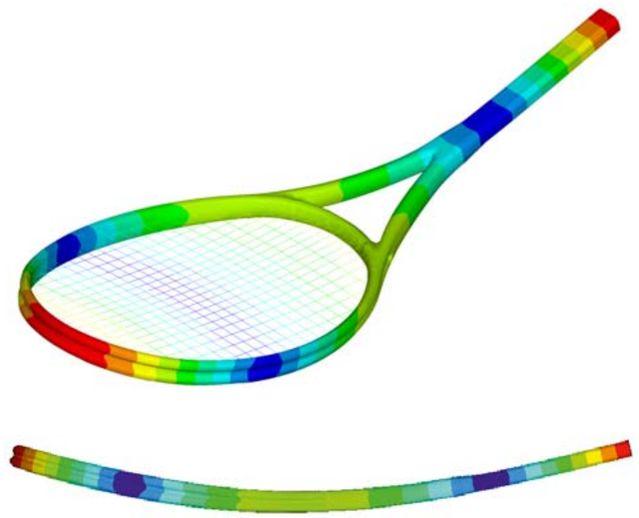


Shaft area of a tennis racket under bending load. The stress level is too high, so engineers reinforced the design.



Second bending mode of a strung tennis racket

Torsion mode of a tennis racquet illustrating how a non-center hit introduces torsion.



First bending mode of a strung tennis racket in elongation. Hitting the ball at the blue node line on the strings does not excite this mode. This is the sweet spot of the racket.