Chair of Structural Analysis
Helmut Masching

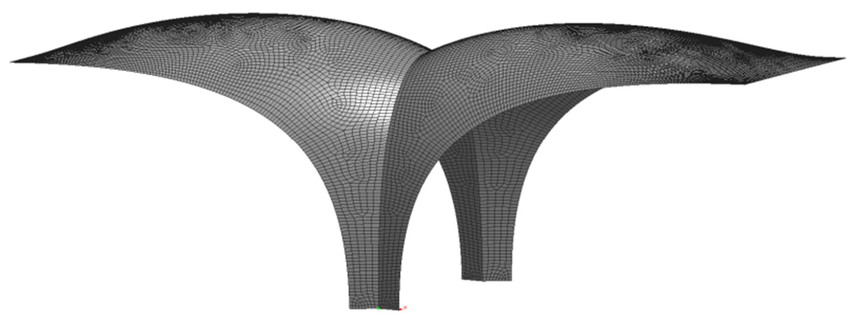
Finite Element Based Structural Optimization

The field of computational structural analysis is gaining more and more importance in structural engineering and product design. In order to obtain an impression about possible approaches of design improvement already in an early planning phase, an efficient optimization tool is desired that requires only few modeling effort. To this purpose the finite element based optimization method is an excellent approach, providing an enormous design space which might contain the complete computational model, leading to the highest possible diversity within the optimization process.

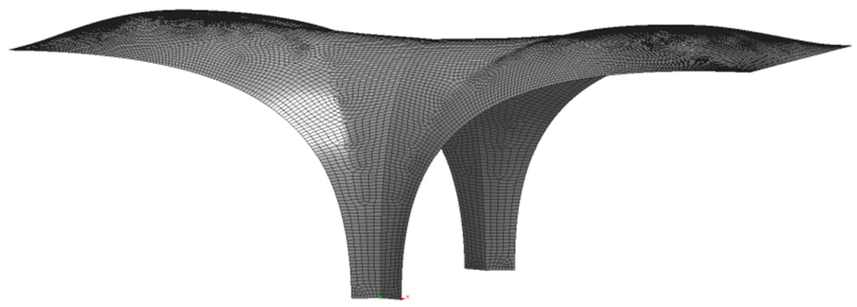
The chair of structural analysis developed the in-house analysis and optimization software ***Carat++*** which allows us to handle all kinds of optimization tasks arising in different disciplines of engineering.

Free shape optimization

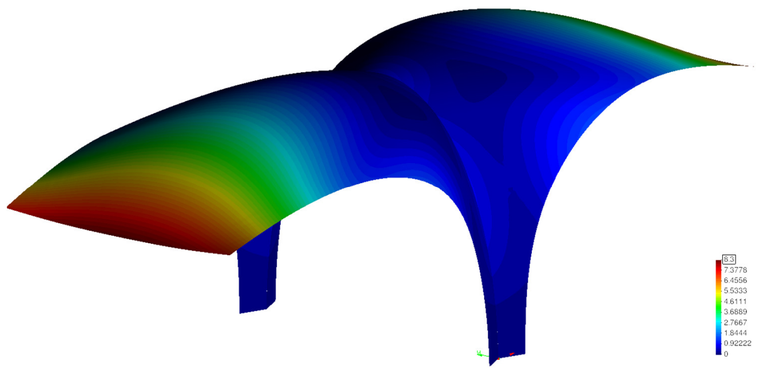
This project was done in cooperation with the architect's office of Foster+Partner. The goal was to maximize the stiffness and so the usage of material of a cantileving roof while the spirit and the light weight appearance of the structure should be maintained as far as possible. To this purpose the edges and the central arch of the roof have been fixed and the inner parts of the surfaces were free to shape optimization (about 16.000 design variables). During the optimization the positively curved surfaces were changed to negatively curve ones and so the maximum displacements could be decreased by a factor of 2.8.



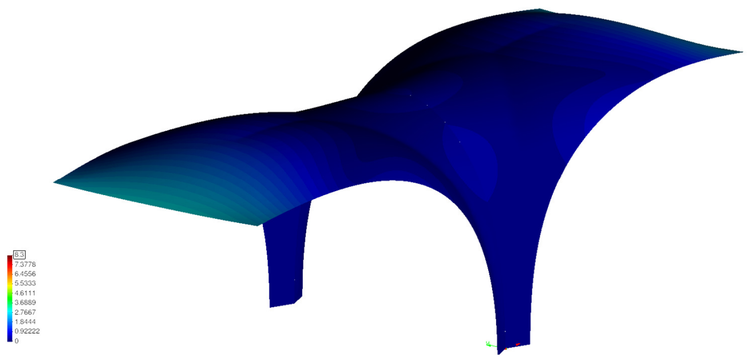
Initial design: positive gaussian curvature



Optimized design: negative gaussian curvature generated



Displacement of initial design

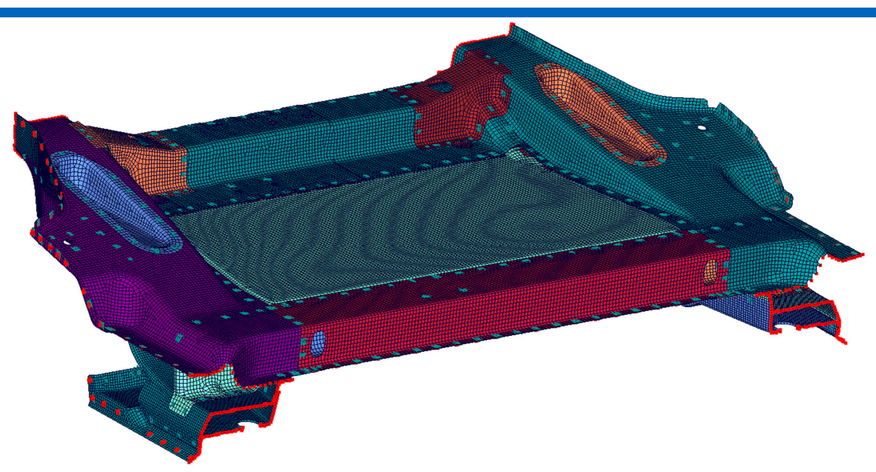


Displacement of optimized design

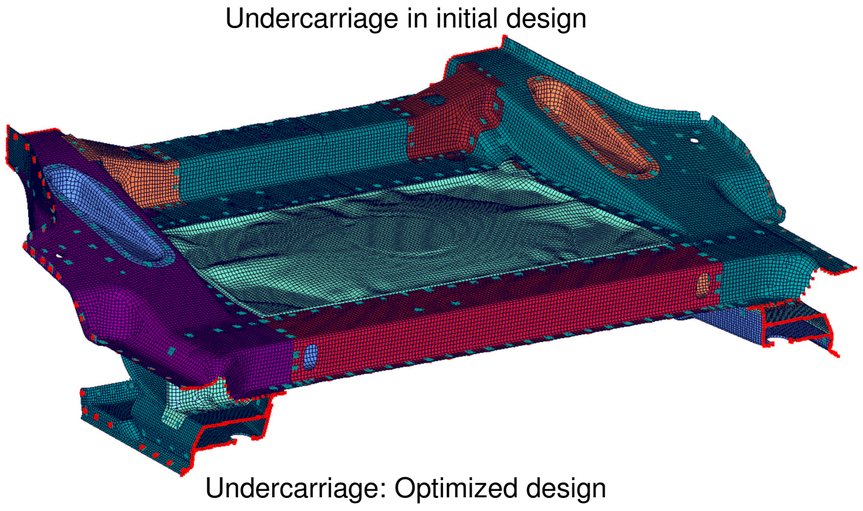
Optimal bead design

The process of beading is a very common and efficient technique in order to increase the bending stiffness of thin metal sheets. Thereby shape and arrangement of the beads are usually done based on experience and the sensitiveness of the engineer to the load carrying behavior of the beaded part. A new approach is to use optimization techniques in order to find mathematically optimal bead designs. To this purpose the finite element based optimization is an ideal tool, as it requires a minimum modeling effort and can be easily integrated into the design process.

The pictures on the right show the bead optimization of an undercarriage.



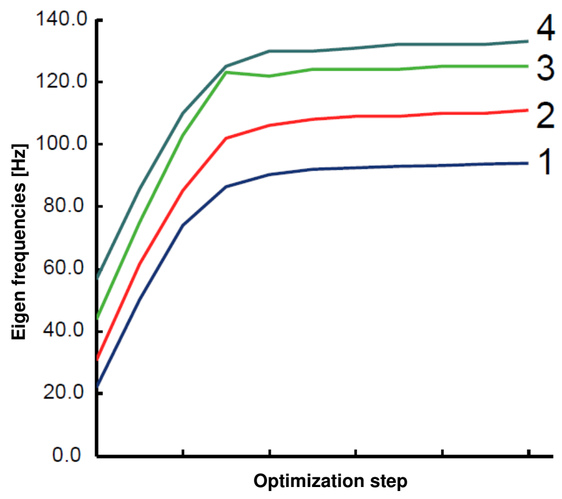
Undercarriage in initial design



Undercarriage: Optimized design

by courtesy of

FEMopt Studios

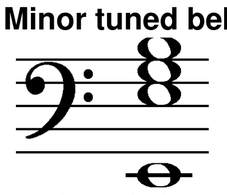


Development of eigen frequencies within the optimization process

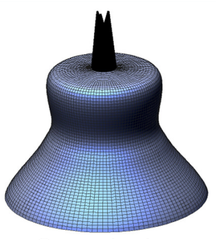
Combined free shape optimization and sizing

This example shows the eigen frequency tuning of a bell where we compare a minor tuned to a major tuned bell. Both optimizations start with an arbitrary geometry where shape and thickness distribution of the model are considered as design variables. Although there is only a small difference of 12 Hz in the 3rd eigen frequency we receive totally different optimized shapes.

Minor tuned bell

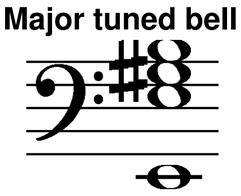


minor triad e

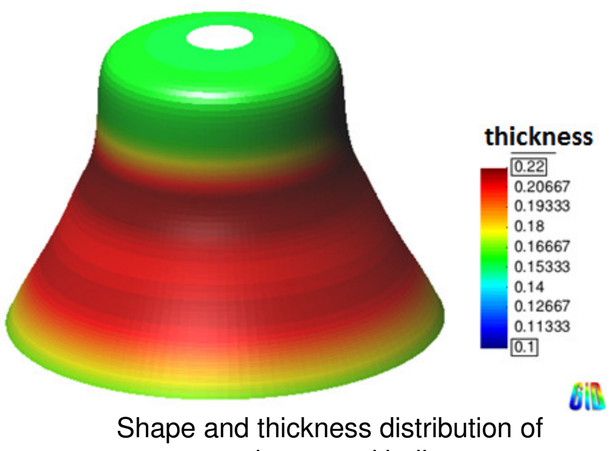


Start design

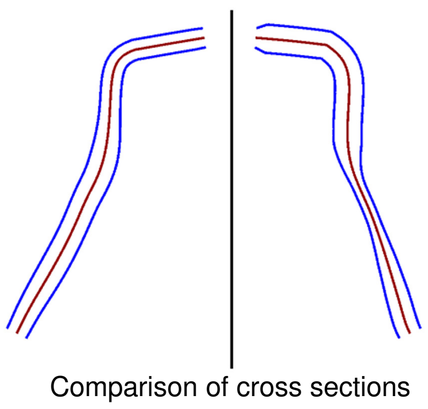
Major tuned bell



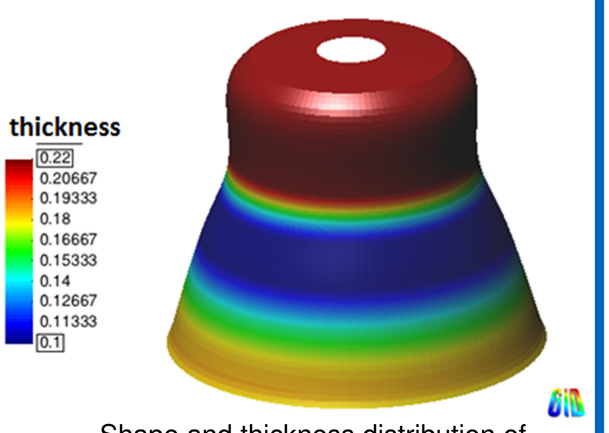
major triad e



Shape and thickness distribution of minor tuned bell



Comparison of cross sections



Shape and thickness distribution of major tuned bell