Better Products in Less Time with Optimization

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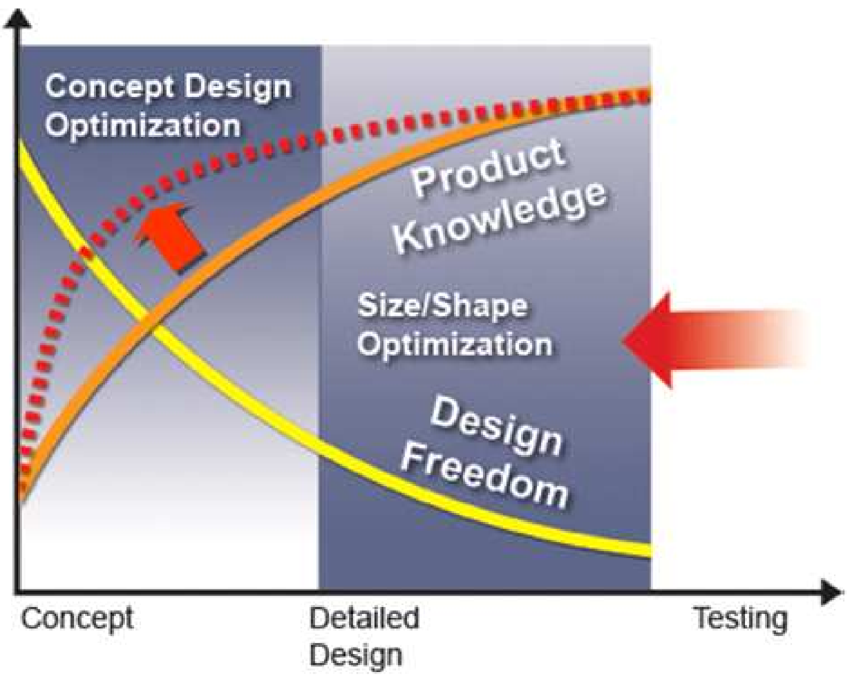
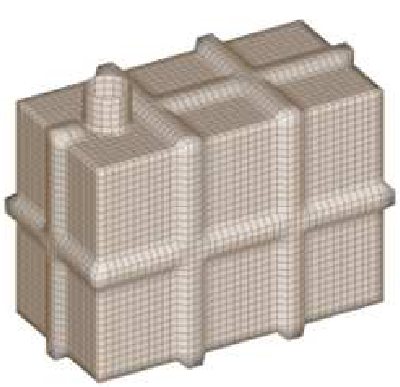
Since graduating from BYU with a Masters in Civil Engineering in 1984, my career has been devoted to the design and analysis of various structures – mostly aerospace. Five years ago I was introduced to the world of optimization as it relates to product design and analysis. For me it was akin to walking out of the darkness and into the light. So in this short article, I will introduce you to optimization and hope to demonstrate how it can help design *Better Products in Less Time*.

So what is optimization and how does it apply to the products you design and analyze? In short optimization is a set of mathematical methods for developing better conceptual designs and for minimizing trial and error in the product fine-tuning process. Optimization answers questions like, “Where do I place the material to most effectively carry loads through my product?” or, “How do I change component features to reduce stresses and meet design requirements?”

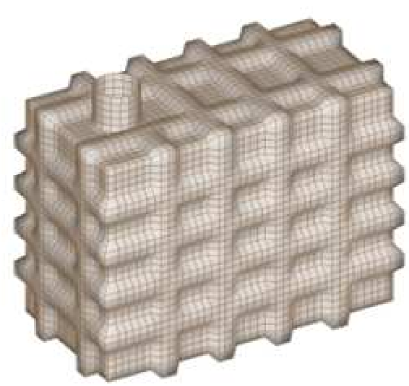


Concept *Design Optimization* results in greater *Product Knowledge* early in the design cycle when you have the most *Design Freedom*. Better concepts result in fewer changes during the *Detailed Design* and *Testing* phases when making changes is both painful and expensive. *Size/Shape Optimization* greatly reduces the trial and error process associated with design fine-tuning. The overall result is *Better Products in Less Time.*

Following are some examples to show how optimization works. We begin with the design of a Pressure Tank where our goal is to minimize tank displacement. We think that if a few ribs are good, then more ribs must be better. But in this case, as the deflection results show, more is not always better.

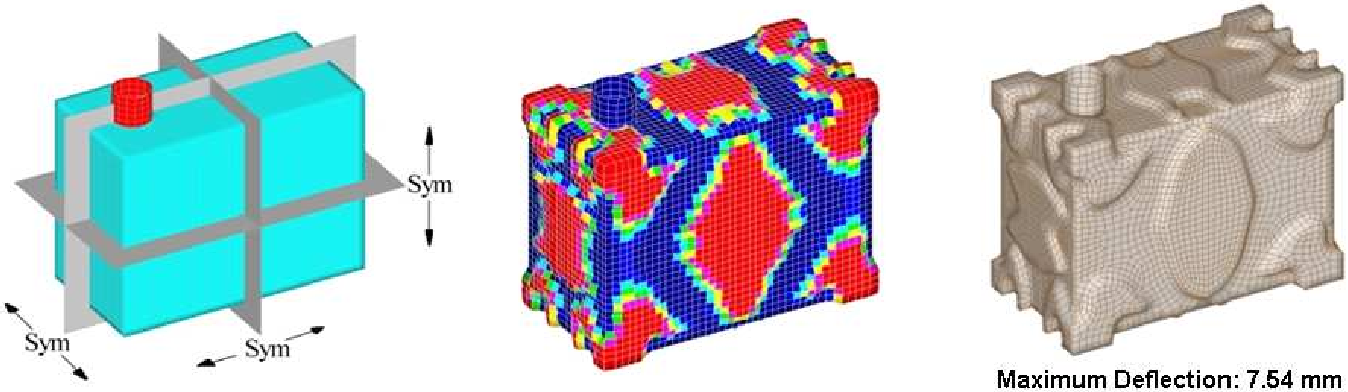


Maximum Deflection: 10.8 mm

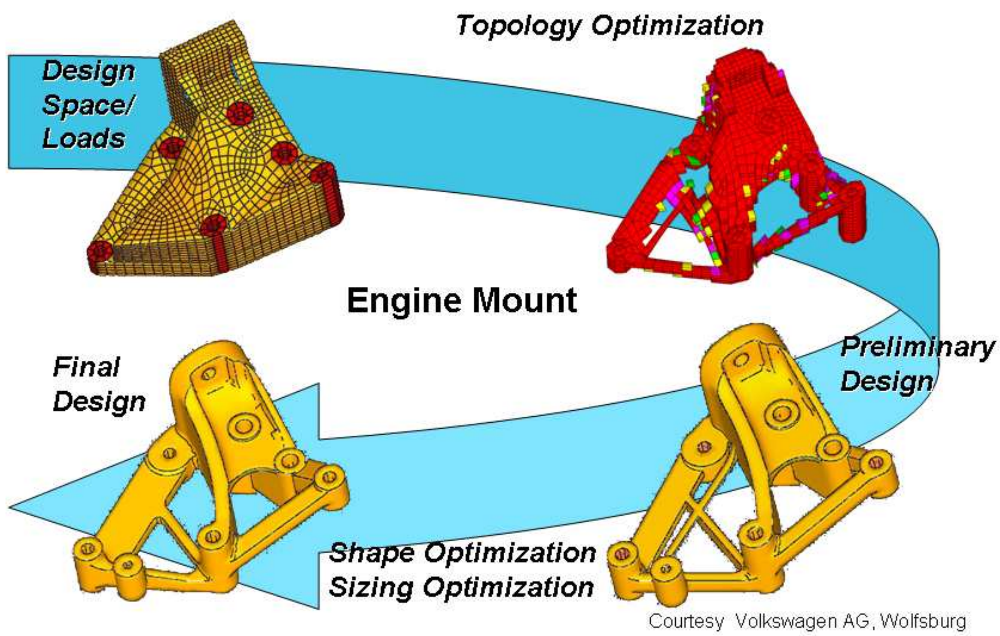


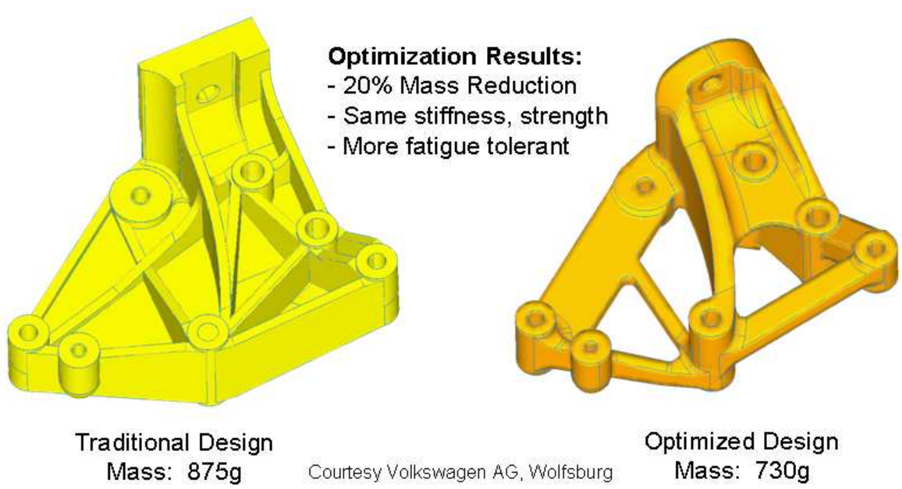
Maximum Deflection: 13.9 mm

So enter stage right, Optimization. The optimization problem is set up by defining three symmetry planes, applying the load cases the tank will experience in operation, and setting a goal to minimize the tank deflection. The solution provided by optimization is counter-intuitive and results in a tank that is both manufacturable and demonstrates minimum tank deflection.



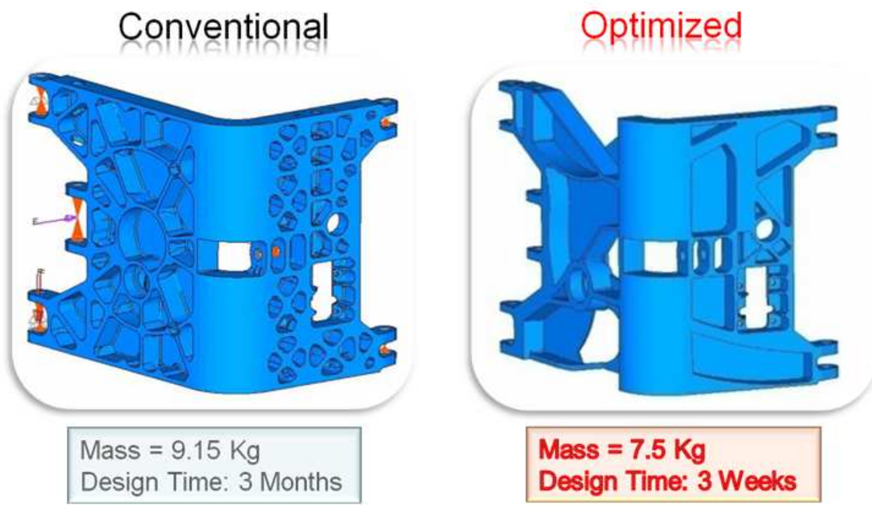
For an engine mount the optimization process begins by defining the available *Design Space*, the space where material can exist. This definition includes identifying bolt-down locations and the critical loads the engine-mount will experience. Next we use *Topology Optimization* to whittle away the design space and place material to most effectively carry the loads. This approach produces a *Preliminary Design*. Finally we fine-tune the design with *Size and Shape Optimization* to ensure that all design requirements such as stress, displacement, buckling, and fatigue are met.





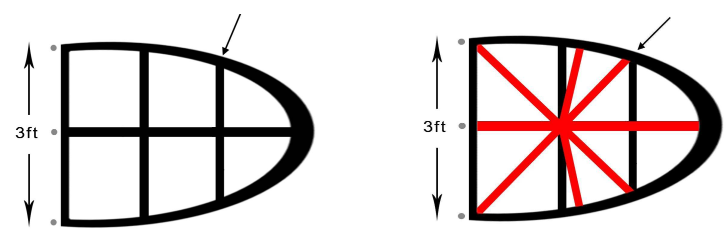
A comparison of the traditional engine mount vs. the optimized engine mount demonstrates the value optimization brings to the design process. The optimized design is simpler, lighter, has the same stiffness and strength, and is more fatigue tolerant.

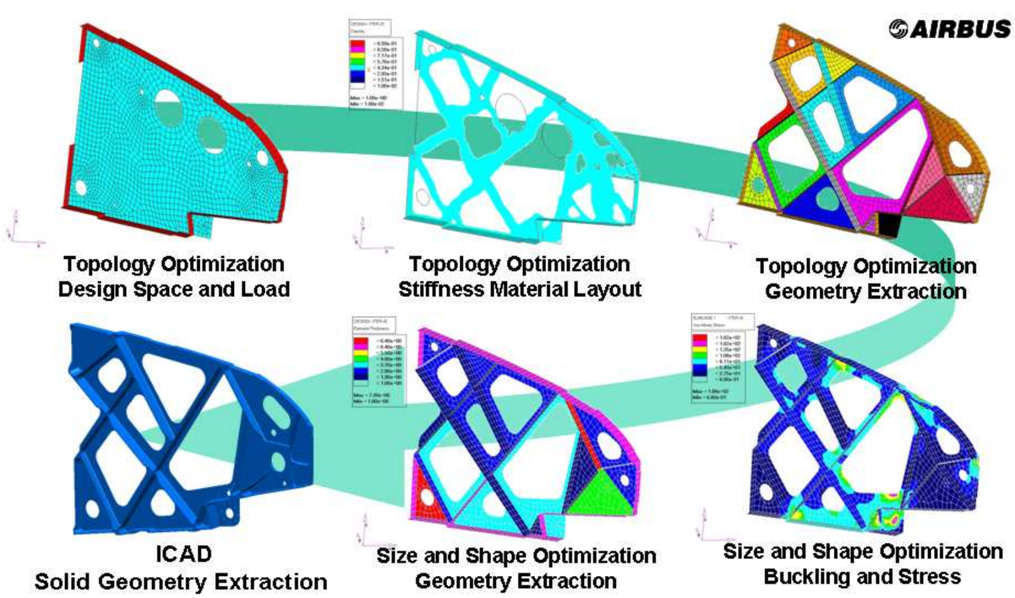
Our third example is a door hinge from a Eurocopter aircraft. Using an optimization process similar to that used for the engine mount, we obtained the following results. Not only was the mass reduced by 18 percent, but the design time was decreased from 3 months to 3 weeks.



Our final example is the AIRBUS A380 Leading Edge Wing Rib package. Traditionally wing ribs have employed a horizontal/vertical stiffener and shear web design. The problem with the traditional design method is that loads come into wing ribs normal to the wing surface. Therefore horizontal and vertical stiffeners do not carry the loads efficiently. The wing rib would be better designed using the stiffener pattern shown in red.

We used the same optimization process described for the engine mount and door hinge to design the Leading Edge Wing Ribs for the AIRBUS A380. Note the non-traditional design.





The real-world results from this optimization effort are as follows:

- 13 ribs designed by 5 engineers in 7 weeks
- 1100 pounds removed from the baseline design
- Over 40 percent weight reduction
- Reduced weight allows 5 additional passengers = $4.5 million over the life of one AIRBUS A380

So there you have it, optimization in a nutshell – something to consider in your quest to design *Better Products in Less Time.*