Case study

Enabling reliable aircraft structures with generative design

MSC Apex Generative Design Enables Design Project to Reduce Two Parts Into One, and Cuts the Maximum Stress in Half

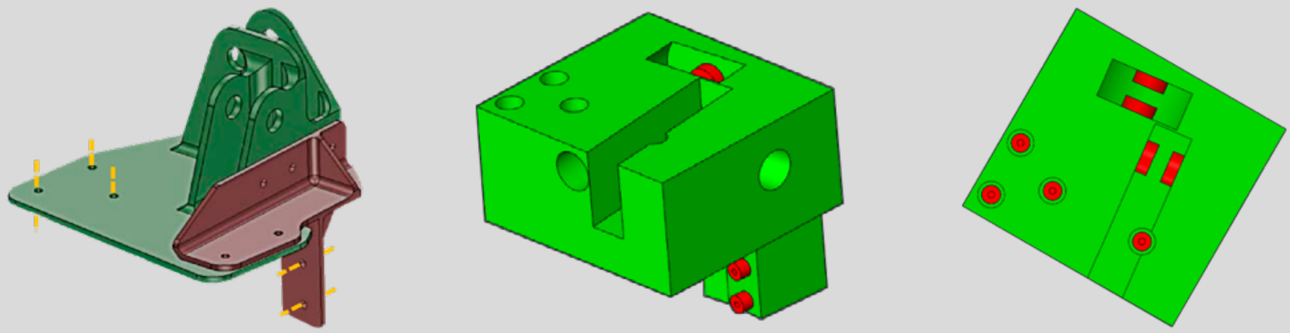


Figure 1 (From Left to Right): The conventional bracket consisting of two parts, which was re-designed into one part using the design space (which can be seen in green) and the non-design space (which can be seen in red).

Challenge

The aerospace industry is one of the most demanding industries in terms of component quality and reliability. There is enormous potential for the use of Additive Manufacturing to produce high-tech parts. This new process provides the opportunity to create a new breed of designs that are function-oriented with optimized and purpose-oriented geometries.

MSC Apex Generative Design's function-oriented component optimization was born out of a research project from the Direct Manufacturing Research Center at the University of Paderborn in conjunction with an industrial partner. An aerospace bracket was identified and selected for the re-design optimization project. The existing design required a two-part assembly in which the individual components were milled from a solid aluminum block and joined with several rivets. This produced a correspondingly high amount of waste in the production process.

Solution

The original part's geometry was used as a starting point for the optimization process in order to define the design space that the optimization engine would use. The original design seen above in Figure 1 (dark green and dark red components) were joined together to form a single design space. The bracket assembly required five connection points (shown in Figure one in orange) to mount to the aircraft. The set of design criteria that the optimized design was required to meet included the design and non-design spaces, connections points, the material properties, and structural loading specifications.

While standard topology optimization software pursues optimization goals such as mass reduction or stiffness increase, MSC Apex Generative Design uses a clearly-defined maximum stress target while creating an optimal lightweight design. During the optimization process, unimportant elements are removed from the design space, resulting in geometry that is geometrically and mechanically sound at each iteration. Due to this innovation, a manual interpretation of the resulting optimization back into CAD geometry is not necessary, thus saving a significant amount of time during the optimization process.

During the optimization process for this component, three design candidates (Figure 2) were generated to meet the challenge. These three design candidates represented the three different algorithms available in MSC Apex Generative Design – Sparse, Medium, and Dense – referring to the three optimization options available. These three design variants ultimately differed in weight only by a few grams and all three of them represented a total weight reduction of 63% compared to the original design. What is of particular interest is the fact that a different number of attachment points to aircraft structure was needed for each design variant. Only three attachment points were needed in the sparse design, four were needed in the medium design, and all five of the original attachment points were used in the dense design. Since the user wanted as evenly distributed of a load transfer as possible, the "medium" design variant with four attachment points was ultimately selected.

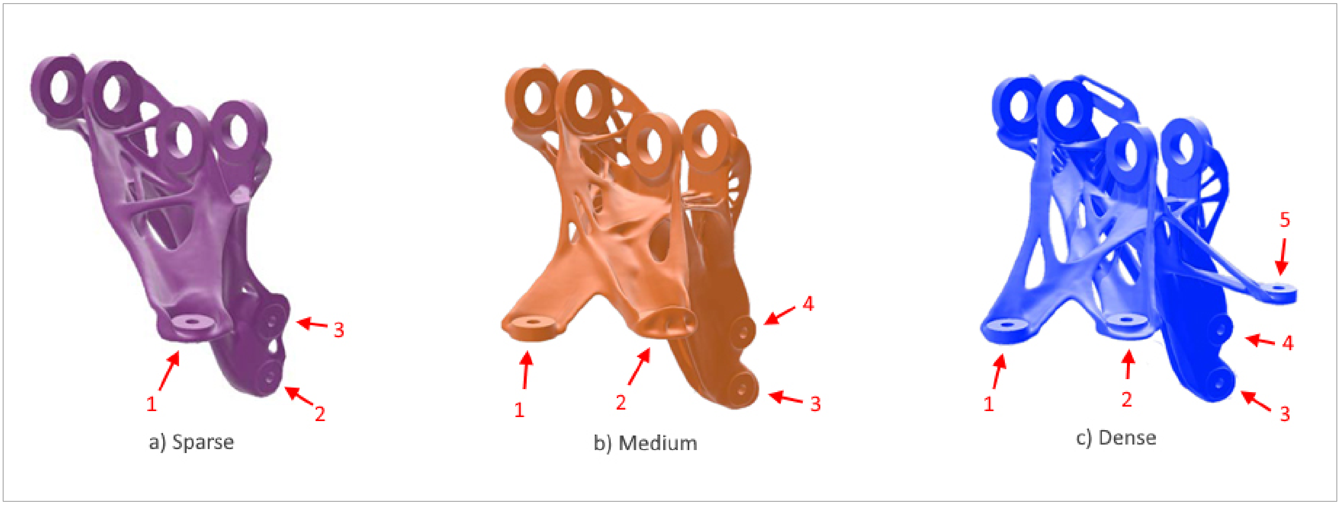


Figure 2: Three different design variants (from left to right): (a) sparse, (b) medium, and (c) dense using the three different settings available in the MSC Apex Generative Design solver. The main difference between the designs is the number of attachment points (Sparse has three, Medium has four, and Dense has five). Version B (Medium) was ultimately chosen as the go-forward design.

Validation

In order to validate this component and its use in an aircraft, a static and dynamic load was applied to the component. The engineers at Paderborn University simulated the different loading conditions and used the Von Mises stresses and the deformation of the model to decide on the strength of the part, and the ultimate validity of the final design. The comparison with the conventionally-designed bracket shows that the optimized structure has become much stiffer and stronger. It can now withstand three times higher loads for load case 1, and 2.1 times as much for load case 2. The combination of the two forces results in a maximum stress of 70% for the ultimate load and 45% for the limiting load case compared to the allowed stress.

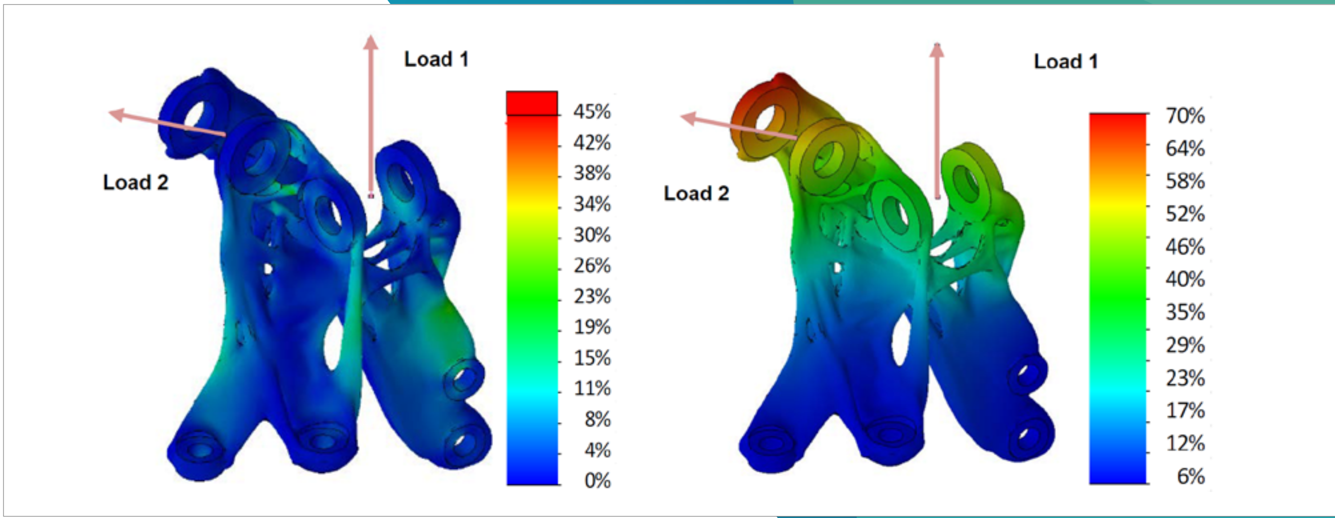
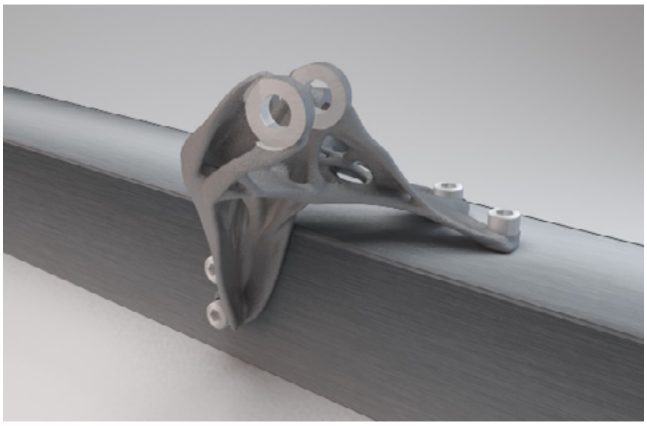


Figure 3: Von Mises Stress and Deformation plots of the final design (normalized to the simulation results of the original bracket). Note that the maximum stress of the final design was 45% of the original design, and the maximum deformation of the final design was 70% of the original design.

Physical testing

To verify that the simulation was correct, and the newly-designed part could withstand the loading conditions that it would experience on the airplane, the part was mounted in a tensile test machine and the maximum load that the original component was designed to was applied. The optimized component passed this loading condition without any defects, and ultimately was able to withstand 225% of the load it was designed for, which proved the structural validity of the optimized design.



Conclusion

Researchers at the University of Paderborn showed that not only did the two-part assembly get replaced by one single part, but the weight of the original assembly was reduced by 63% and the maximum stress was reduced by 55%. Also, as an unexpected bonus, once the optimized part was found, only four of the five original attachment points were ultimately needed. One of the most beneficial aspects of MSC Apex Generative Design was the innovative, easy-to-use interface, which did not require an expert in Finite Element Modeling (FEM).

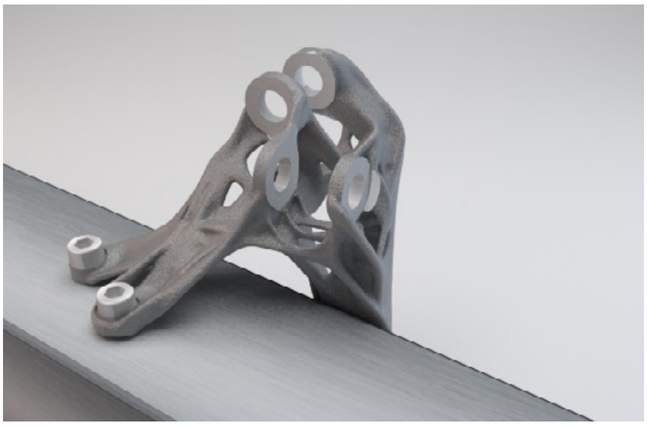


Figure 4: 63% more lightweight is the optimized design of this aerospace bracket

Source: Klippstein et al: "DEVELOPMENT, PRODUCTION AND POST-PROCESSING OF A TOPOLOGY OPTIMIZED AIRCRAFT BRACKET", Conference Proceedings, 30th Annual International Solid Freeform Fabrication Symposium Austin-Texas-USA, August 2019

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