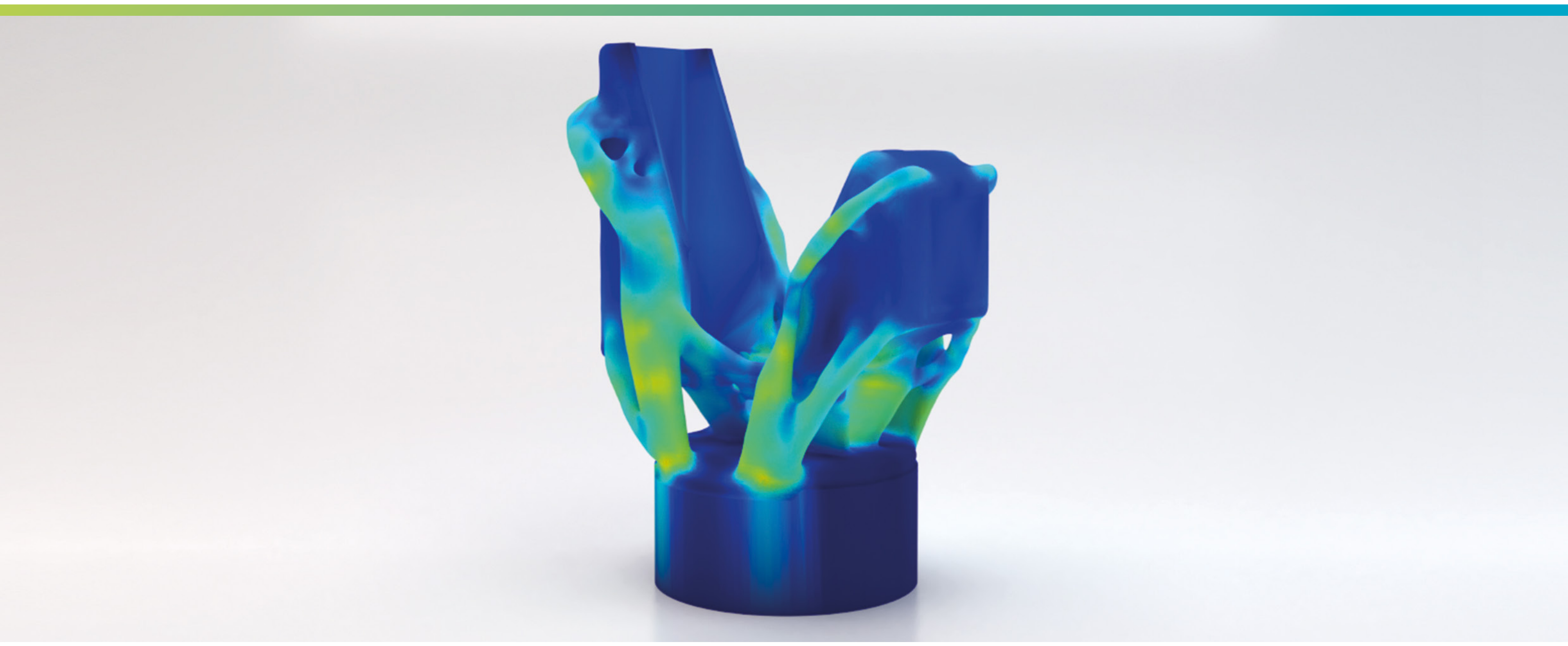
HEXAGON

How generative design was used to get a legacy train part into shape for additive manufacturing

Reduce additive production costs with custom, weight-optimised designs, and produce spare parts flexibly without conventional tools



Deutsche Bahn, SLM Solutions, and Hexagon joined forces to redesign a hinge for a cargo wagon and optimise the new design for additive manufacturing. The weight-optimised result generated by MSC Apex Generative Design software enables cost-efficient production through 3D printing.

Rugged transportation assets such as freight cars are characterized by a service life of several decades. When defects in these assets occur, the procurement of spare parts poses major challenges for operators, as it is often impossible to keep spare parts in stock over long periods of time.

Operators and manufacturers of these items are thus challenged with procuring or manufacturing individual spare parts for continued operation without access to the original tools or part data used to make the part. Additive manufacturing makes it possible to flexibly produce spare parts without conventional tools.

Application and challenge

The problem with producing very old components using conventional manufacturing processes is the extremely long lead times and high costs. The production of tools or semi-finished products takes a lot of time, as machines must be set up and retooled.

With additive manufacturing, production can be done much faster and more flexibly; especially when dealing with a component defect, time can be a decisive factor. To complicate matters, however, conventional designs can be problematic for additive processes; they can require extensive production time because a lot of additive material must be molten. In this context, both material and machine hours are significant cost drivers, which need to be reduced as much as possible.

The component to be optimised in this case was a switch shaft for the automatic coupling of an open bogie bulk freight car for ore transport. Using this component, the train operator can switch between the manual and automatic coupling of the 15 m long wagon and manually release the parking brake of the freight wagon with a loading space of over 60 m³ capacity. Most of the wagons that use this component were put into use between 1978 and 1983.

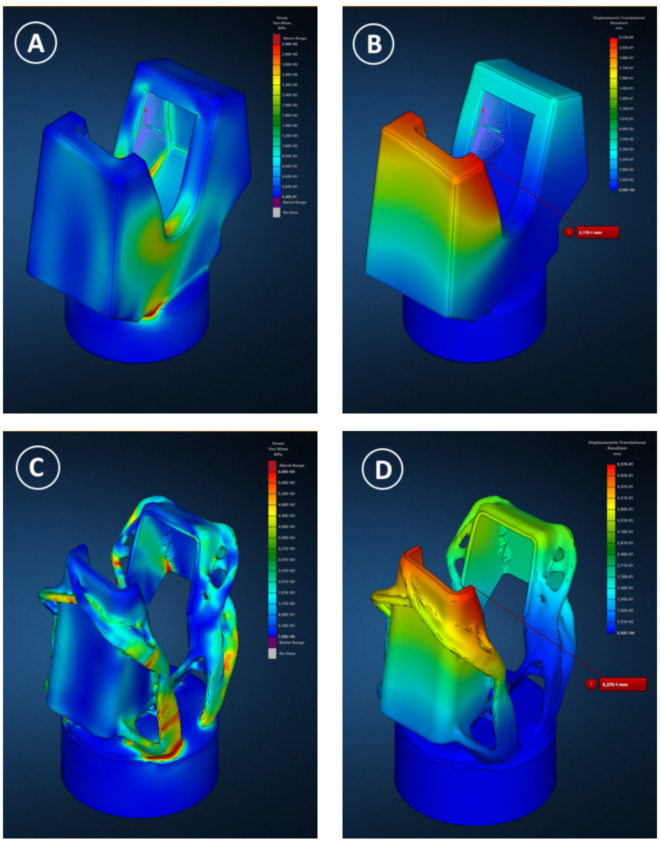
Integrated lightweight design with Generative Design

To optimise part design, the user first imported the original component design into MSC Apex Generative Design software and expanded the design space (the area in which the algorithm is allowed to place material) based on available space with the help of the software's geometry tools. The material of the original component was malleable cast iron and was changed to 316L stainless steel for use in additive manufacturing to allow for AM fabrication. Functional surfaces were given an allowance for subsequent machining and, as non-design areas, could not be altered by the algorithm.

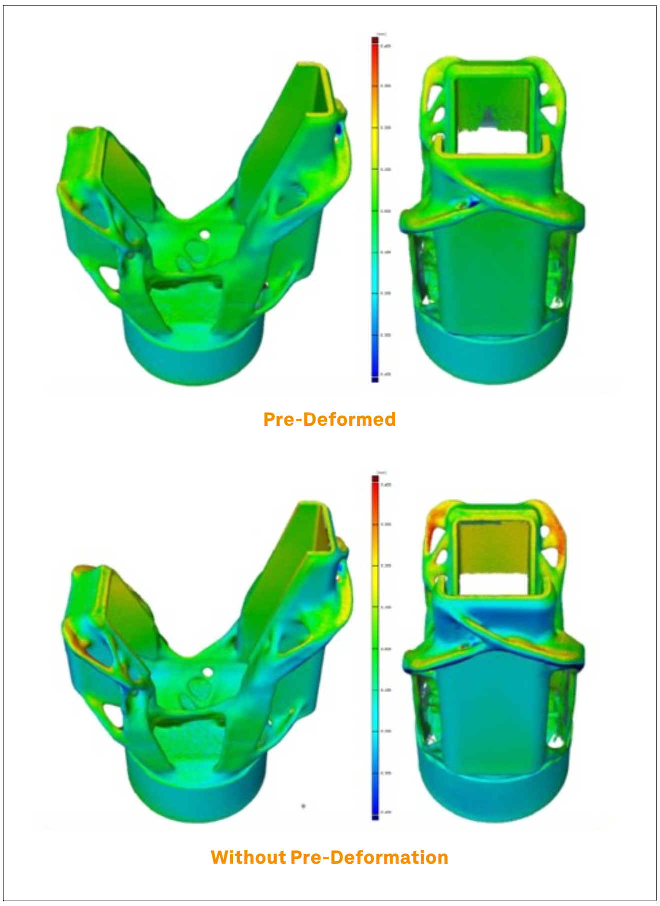
The various forces that occur in operation were added and combined to load cases for optimisation. Optimisation could then start and, with different values for maximum allowable stress, several design alternatives could be generated.

The most promising result reduced the weight to half of the original design. With the help of MSC Apex Structures, the results were further assessed by employing FE reanalysis: The deflection under load increased compared to the solid original design but was still within a non-critical range of half a millimetre. More relevant was the high weight and volume reduction needed to reduce production costs for additive manufacturing. The stress values remained below the permissible material stress, even in critical areas.

With MSC Apex Generative Design, conventional component designs can be optimised and made suitable for additive manufacturing in a minimum amount of time — even without special simulation expertise.



Comparison of the conventional design (top, A & B) with the optimised design (bottom, C & D), with 50% weight reduction: Due to the design space, both designs have a stress peak at the bottom centre (cf. A & C). Deformation under load (cf. B & D) is most prominent at the top height in both variants, but within the tolerance range.



On the top, the measurement result of the pre-deformed part can be seen, and it is significantly lower than that of the part on the bottom, which is unadjusted. Thus, Simufact Additive achieved significant improvement in part quality. Source: SLM Solutions.

Manufacturing simulation and warpage compensation

The process simulation performed with Simufact Additive software was able to solve two key challenges for the printing of the part: Support structure optimisation and distortion compensation. The generated geometry data was loaded into the simulation software and completely calculated within a few hours. The entire production process, including post-processing, could be efficiently set and simulated, including removal from the build platform, post-heat treatment, and more.

The user could optimise printing orientation to enable the best possible printing result with few support structures. In addition, the software could determine any distortions that would occur during the printing process and modify the CAD geometry so that it was very close to the target geometry.

To verify this in practice, four components were built by project partner SLM Solutions, two compensated and two uncompensated. The build job for the stainless-steel components, each measuring approx. 15 x 9 x 3 cm, took 14 hours on the SLM 280 2.0 Twin machine, with approx. 1800 layers in 50 µm layer thickness. Subsequently, the parts were examined by SLM Solutions for their accuracy and deformation. This clearly shows that the preformed components are significantly less deformed than the non-optimised components. Virtual production simulation therefore demonstrably brings decisive advantages for the quality and dimensional accuracy of the components.

Summary

Many capital assets, such as freight cars, are in service for decades and continue to require replacement components for proper operation. This can be a challenge, however, as lead times are lengthy and the suppliers and tools that can deliver replacement parts using conventional processes are difficult to find. In this case, additive manufacturing offers much more flexible, tool-free production with short delivery times.

An additional challenge, however, is that performing additive manufacturing using classic component designs results in components being produced poorly or not at all. In any case, legacy parts tend to be very expensive to produce due to the materials used and associated machine times. Therefore, it is necessary to generate manufacturable, cost-efficient lightweight designs for additive manufacturing processes.

With MSC Apex Generative Design, conventional component designs can be optimised and made suitable for additive manufacturing in a minimum amount of time — even without special simulation expertise. In combination with manufacturing simulation, Simufact Additive for metal and Digimat-AM for polymer, users gain access to additive technology without requiring that they have expert knowledge of their own.

The tools can be used to generate optimal structures adapted for manufacturing and to optimise the production process. The manufacturing simulation of the generated structure optimises critical elements of the manufacturing process, such as distortion and induced stresses, to manufacture high quality components. For the application at hand, the weight was reduced by half and the production-induced deformation was significantly reduced through pre-deformation.

The four printed test objects made of 316L in 50 µm layer thickness on the build platform with the support structure. Source: SLM Solutions.

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Our technologies are shaping production and people-related ecosystems to become increasingly connected and autonomous – ensuring a scalable, sustainable future.

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