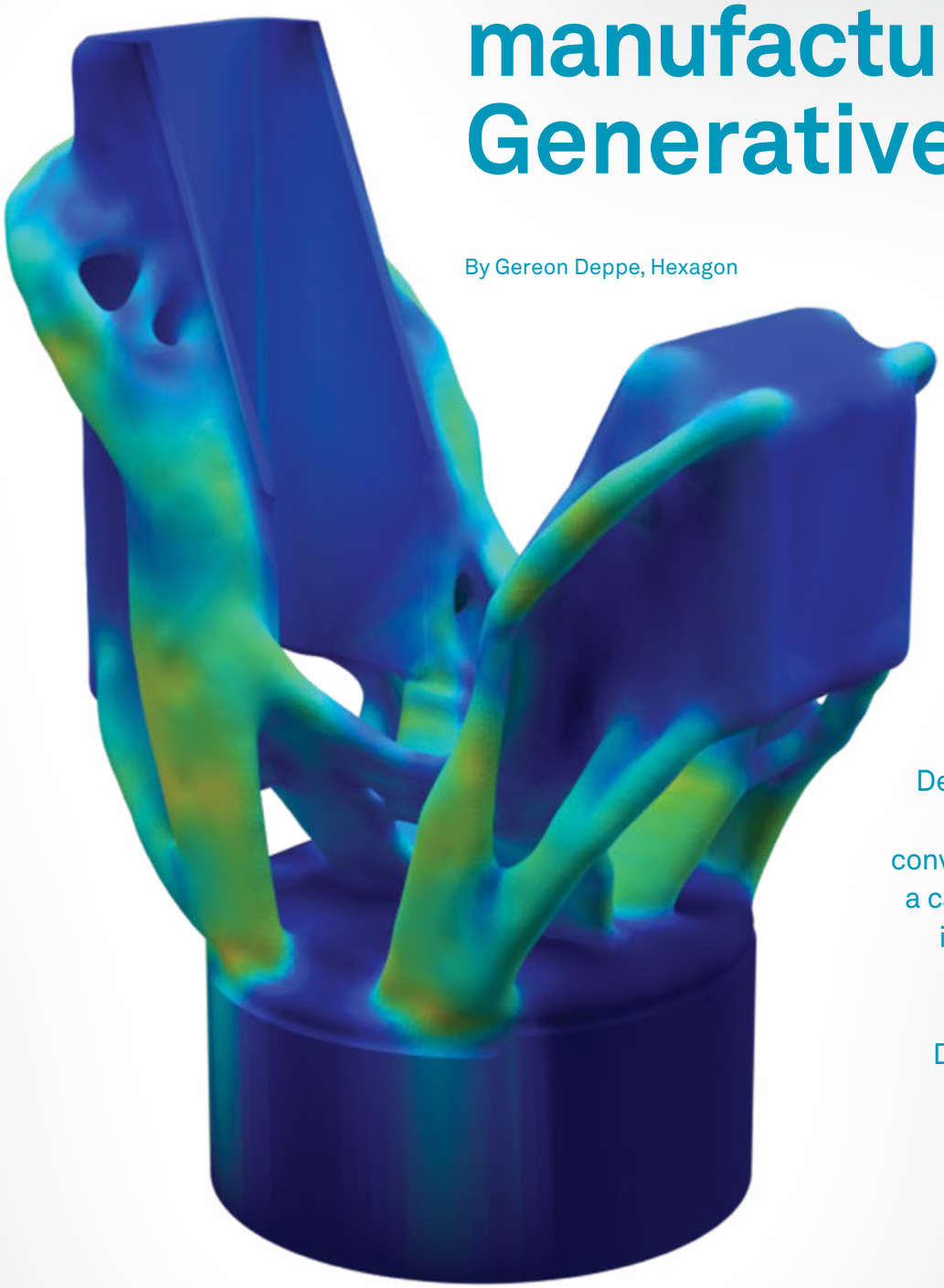
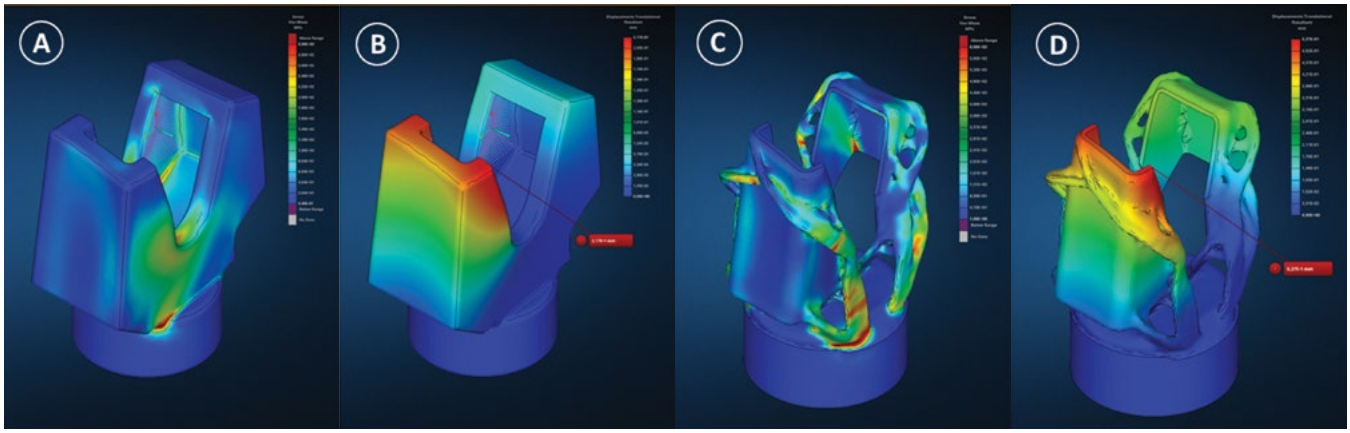
How to bring an aged train spare part in shape **for additive manufacturing with Generative Design**

By Gereon Deppe, Hexagon



In a joint innovation project, Deutsche Bahn, SLM Solutions and Hexagon optimised a conventionally designed hinge of a cargo wagon and redeveloped it for additive manufacturing. The weight-optimised result from MSC Apex Generative Design enables cost-efficient production through 3D printing.



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

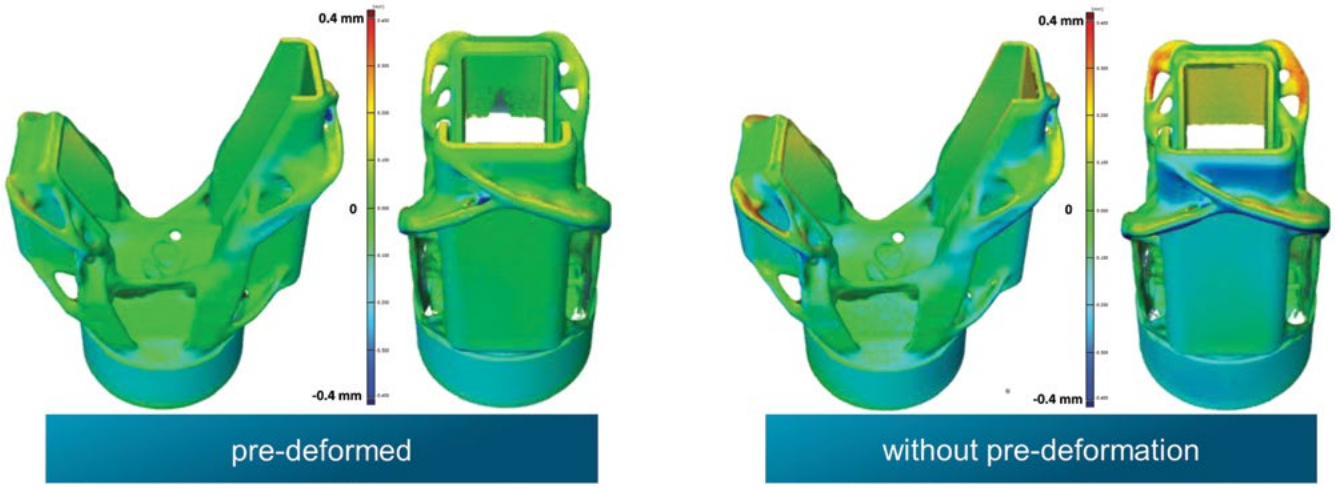
Reduce additive production costs with customised, weight-optimised designs and produce spare parts flexibly and without tools

Assets such as freight cars are characterised by a service life of several decades. When defects occur in the assets, the procurement of spare parts poses major challenges for operators, as it is often not possible to keep spare parts in stock over such a long period of time. Operators and manufacturers of these items are thus confronted with the need to procure or manufacture individual spare parts for continued operation without being able to use the original manufacturing tools or having the original part data. With additive manufacturing, there is now the possibility of producing spare parts without tools and thus in a highly flexible manner.

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, machines have to be set up and retooled. With additive manufacturing, this can be done much faster and more flexibly; especially against the background of a component defect, time can be a decisive factor here. However, the conventional designs themselves are also problematic, as they are difficult or impossible to manufacture with additive manufacturing and can additionally require very long production times, as a lot of material has to 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 here is a switch shaft for the automatic coupling of an open bogie bulk freight car for ore transport. With this component, the train operator can switch between the manual and



On the left, the measurement result of the preformed part can be seen, which is significantly lower than that of the right, unadjusted part. Thus, Simufact Additive could achieve a significant improvement of the part quality here. Source: SLM Solutions

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 were delivered in 1978 and the following five years.

Integrated lightweight design with Generative Design

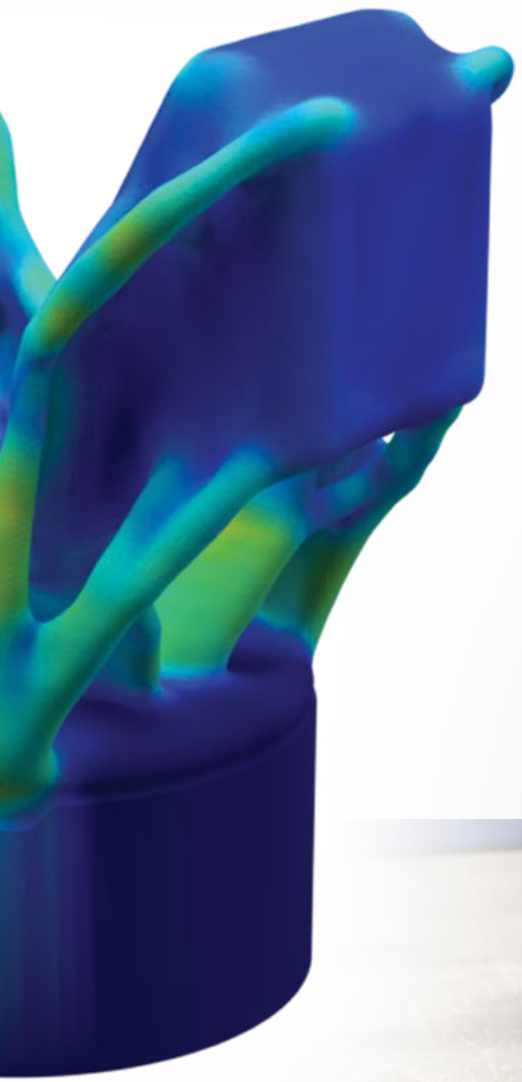
For the optimisation, the user first imported the original component into MSC Apex Generative Design and expanded the design space (the area in which the algorithm is allowed to place material), based on the available space, with the help of the geometry tools. The material of the original component was malleable cast iron and has been changed to 316L stainless steel for use in additive manufacturing to allow AM fabrication. Functional surfaces have been given an allowance for subsequent machining and, as non-design areas, must not be altered by the algorithm. The various forces that occur were added and combined to load cases for the optimisation. Then the optimisation could start and with different values for the maximum allowable stress, several design alternatives could be generated directly. The most promising result reduced the weight to half of the original design. With the help of MSC Apex Structures, the results have been further assessed by employing FE reanalysis: The deflection under load has increased compared to the solid original design but is still within a non-critical range of half a millimetre. More relevant is the high weight and volume reduction to reduce production costs for additive manufacturing. The stress values are still below the permissible material stress, even in critical areas.

Manufacturing simulation and warpage compensation

The process simulation with Simufact Additive 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, can be set and simulated, i.e., removal from the build platform, post-heat treatment and more.

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

To verify this in practice, four components were built by the 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. However, there is often a lack of suppliers, tools or the time until these can be delivered using conventional processes and missing semi-finished products. Here, additive manufacturing offers a much more flexible, tool-free production with short delivery times. However, classic component designs are problematic here, as they can be produced poorly or not at all with additive manufacturing, but in any case, are very expensive due to the materials used and the associated machine runtimes. Therefore, it is necessary to generate well manufacturable, cost-efficient lightweight designs. With MSC Apex Generative Design, conventional component designs can be optimised and made suitable for additive manufacturing in a minimum of time - even without special simulation expertise. In combination with manufacturing simulation, Simufact Additive for metal and Digimat-AM for polymers, users gain access to additive technology even without having 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 the components with high quality. 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 and still with support structure. Source: SLM Solutions