Case study

Simufact Engineering provides the GreenTeam & Renishaw with a complete AM Process Simulation Solution

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The University of Stuttgart's Formula Student race car with additively manufactured wheel carriers

Overview

There is an ongoing development in the automotive industry of enhancing vehicles with more robust and powerful engines for more agile movements. In addition to engine power or traction control, the weight of the vehicle also makes a significant contribution to the performance on the track.

One of the Formula Student teams, The GreenTeam in Stuttgart, Germany, reached out to Renishaw to support them in achieving this task for their electric racing car. While the GreenTeam was working on the redesign of the wheel carrier, which was originally made of aluminum, they tried in vain to find a sponsor who would be able make the improved wheel carrier design. These problems arose because optimizing the weight and force parameters would result in component features (e.g. cavities) which are difficult to achieve with conventional manufacturing methods, especially as titanium is notoriously difficult to machine.

With its metal powder-based additive manufacturing system, the British engineering technology company Renishaw, met these requirements exactly. Renishaw is one of the world leaders in the field of additive manufacturing (also referred to as metal 3D printing), where it is the only UK based business that designs and makes industrial machines, capable to “print” parts from metal powder. However, realizing such a complex geometry is quite challenging.

Renishaw solution center in Germany turned to Simufact Engineering AM solution, Simufact Additive, as their tool of choice to optimize the manufacturing with the goal of reducing the high distortion of the part and the separation of the support structures.

Challenge:
- Cracks located at the interface between the part/base plate and the part/support
- Undesired distortion

Solution:
- Failure analysis by simulation
- Distortion compensation by adding inserts and a new support structure

Products used:
Simufact Additive

Customer:
Renishaw GmbH

Challenge

Additive manufacturing (AM) is a novel method for manufacturing complex lightweight parts from 3D models, where traditional methods will increase costs through tooling or longer production times. Although, additive manufacturing has been used for many decades, is only in recent years that has caught the attention of the automotive industry.

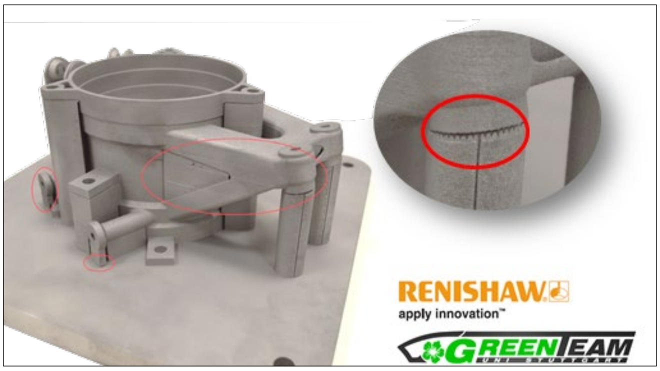


Figure 1 A: Printed wheel carrier. Separation observed in the support structure

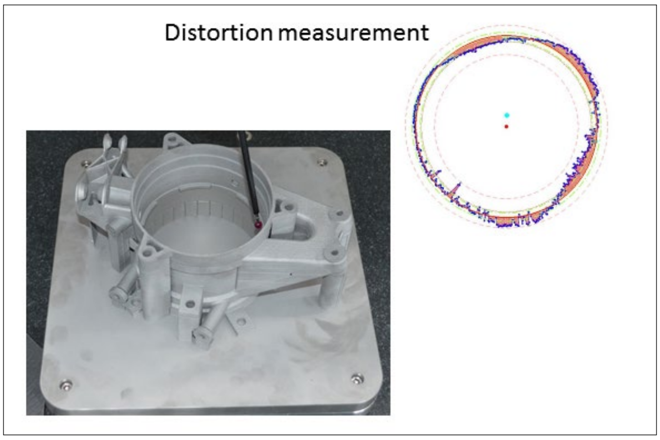


Figure 1 B: Measurement of the distortion at the top of the part

Between the metal based powder approaches, a powder bed fusion machine from Renishaw was used to print the wheel carrier of the formula student car. The laser machine fuses selected regions of a powder bed. After a layer is scanned and selected material is melted, a new layer is deposited. Similar to other thermal analysis, many process parameters will influence the quality of the printed part (i.e. build speed, power source, layer thickness).

Controlling the process parameters represents a challenge - even multiple tests do not necessarily lead to optimal settings. Therefore, it is common to print parts out of tolerance or with visible damage. In the case of the wheel carrier, Renishaw’s engineers observed cracks located at the interface between the part/base plate and the part/support (figure 1A). In addition, a scan performed at the top of the part showed an undesired distortion (figure 1B).

Renishaw needed a simulation solution to enable their design team to not only optimize the design for a lighter weighted vehicle, but also for a “first-time-right” printed part. Regarding the high costs and efforts in the additive

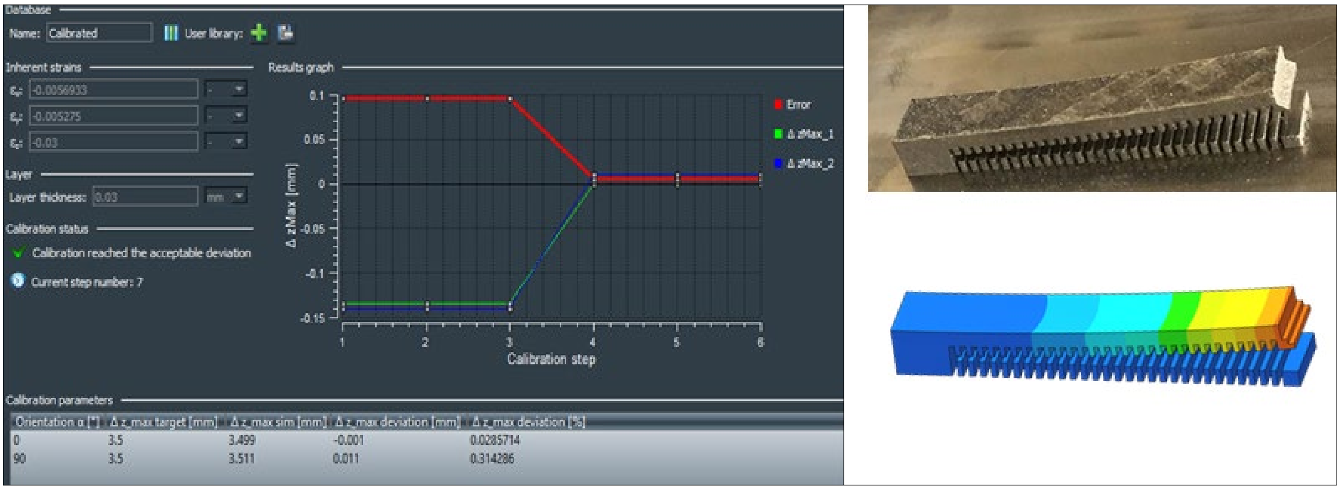


Figure 2: Calibration of inherent strains

manufacturing this leads to a higher productivity and is therefore a huge benefit for Renishaw. In fact, process simulation has become a well-established method due to the increasing precision and reliability of simulation results, shorter and more practical calculation times, and the improved usability of the simulation software. Renishaw therefore contacted Simufact Engineering, known as simulation experts in manufacturing technology, to predict the build process to eliminate any distortions or any separation of the support structures.

Solution

Simufact Engineering's software tool Simufact Additive offers a macro scale approach that can be used to optimize not only the stage where the part is built, but also the subsequent process chain. The macro analysis considers the inherent strains that are induced by the manufacturing process. These inherent strains comprise plastic, thermal, creep and phase transformation strains.

In Simufact Additive, the inherent strains can be easily calibrated with a calibration module. To calibrate the inherent strains, Renishaw printed two cantilever samples at 0° and 90° of orientation with the same machine parameters used to print the part. The material used for the calibration (TiAl6V4_powder) is part of Simufact Additive's material database. After printed, the cantilevers were cut in the middle of the toothed section (height = 3 mm) and the distortion was measured. To maintain a reference point and prevent rigid body motion, the cantilevers cannot be removed completely from the base plate. The displacement measured in each cantilever is then used to calibrate the inherent strains. After 7 simulations, the calibration reached the target distortion (figure 2) with a maximum acceptable deviation of 0.3%.

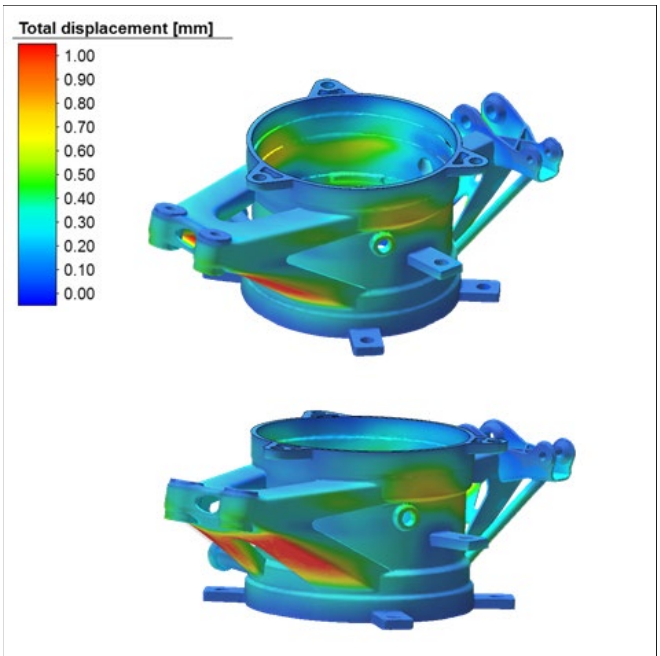
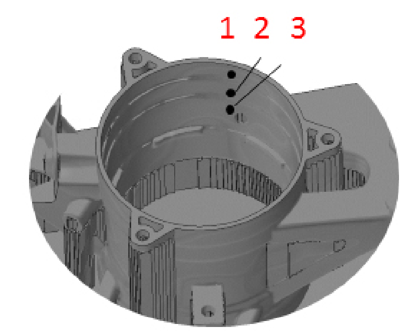


Figure 3 A: Distortion B- Comparison between experimental and predicted distortion



Point	Experiment (mm)	Predicted (mm)
1	0.3532	0.3539
2	0.5517	0.5527
3	0.5920	0.5931

Figure 3 B: Comparison between experimental and predicted distortion

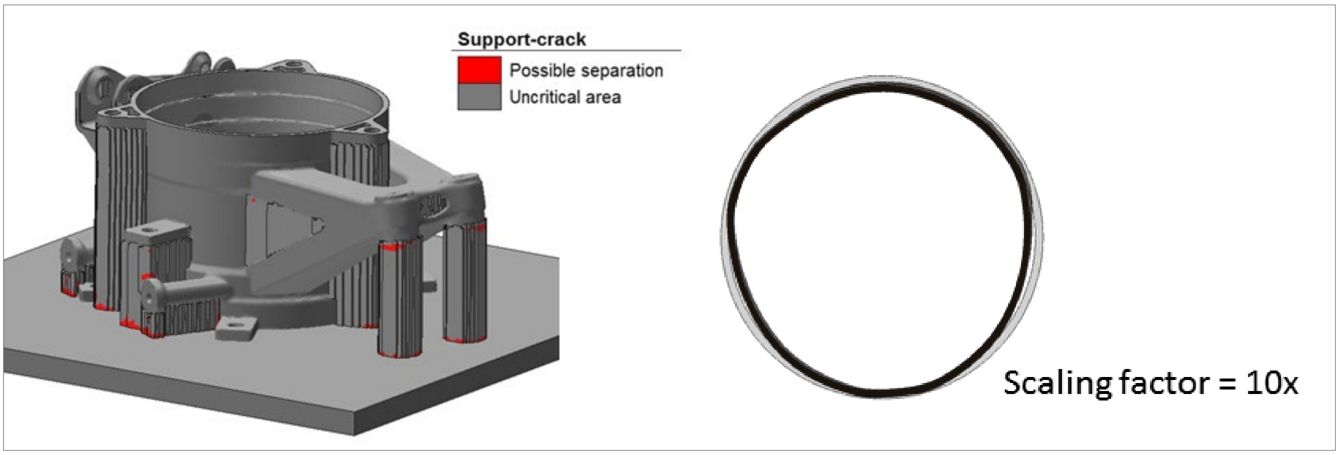


Figure 4: Simulation results with calibrated inherent strains. A- fracture areas, B- Shape of the part with scaling factor 10x

Next, the calibrated inherent strains were used to simulate the part. To overcome the limitation of meshing complicated parts and due to the similarity with the layer by layer manufacturing process, Simufact Additive uses a voxel mesh of cubic shape. The voxel elements represent several layers of powder material that are sequentially activated. In the analysis, the support structures were imported from a CAD file and modeled with the same titanium alloy used in the part. The part and supports were placed on a base plate, and modeled with 82 layers of voxel elements of 0.06 mm of powder layer thickness. A voxel element size of 1 mm was used to discretize the components (part, supports and base plate), where every element consisted of around 17 powder layers.

The second stage of this study was to evaluate the accuracy of the simulation results. Renishaw's engineers measured the distortion at three locations of the part. The predicted distortion is in good agreement with reality (figure 3). Even more, the cracks observed by Renishaw's engineers in the wheel carrier are also predicted in the simulation results (figure 4A).

After further analysis, it was noticed that these are regions with high maximum principal stresses that led to failure after printing the part. Finally, the shape of the part in figure 1B can be compared with the simulation result in figure 4B.

Results

To compensate the distortion observed in the inner region, a new design has been proposed. 4 inserts were added to the part and a new support structure was created with Simufact Additive (figure 5A). Compared with figure 3A, the new results in Figure 5B show that the localized distortion has been reduced in all regions. Also, the inner section is predicted to maintain its cylindrical shape (figure 5C). Finally, it is shown that the distortion has been reduced with respect the original configuration (figure 5D). Although a new design has been proposed, other changes can be easily analyzed with Simufact Additive such as the use of distortion compensating designs based on pre-distortion or changes in the process chain.

About

Renishaw is a world leader in the field of additive manufacturing (also referred to as metal 3D printing), where it is the only UK business that designs and makes industrial machines which 'print' parts from metal powder. The majority of Renishaw´s research and development and manufacturing is carried out in the UK. The Renishaw Group currently has more than 70 offices in 35 countries, with around 4,000 employees worldwide. Around 2,600 people are employed within the UK where the company carries out the majority of its research and development and its manufacturing.

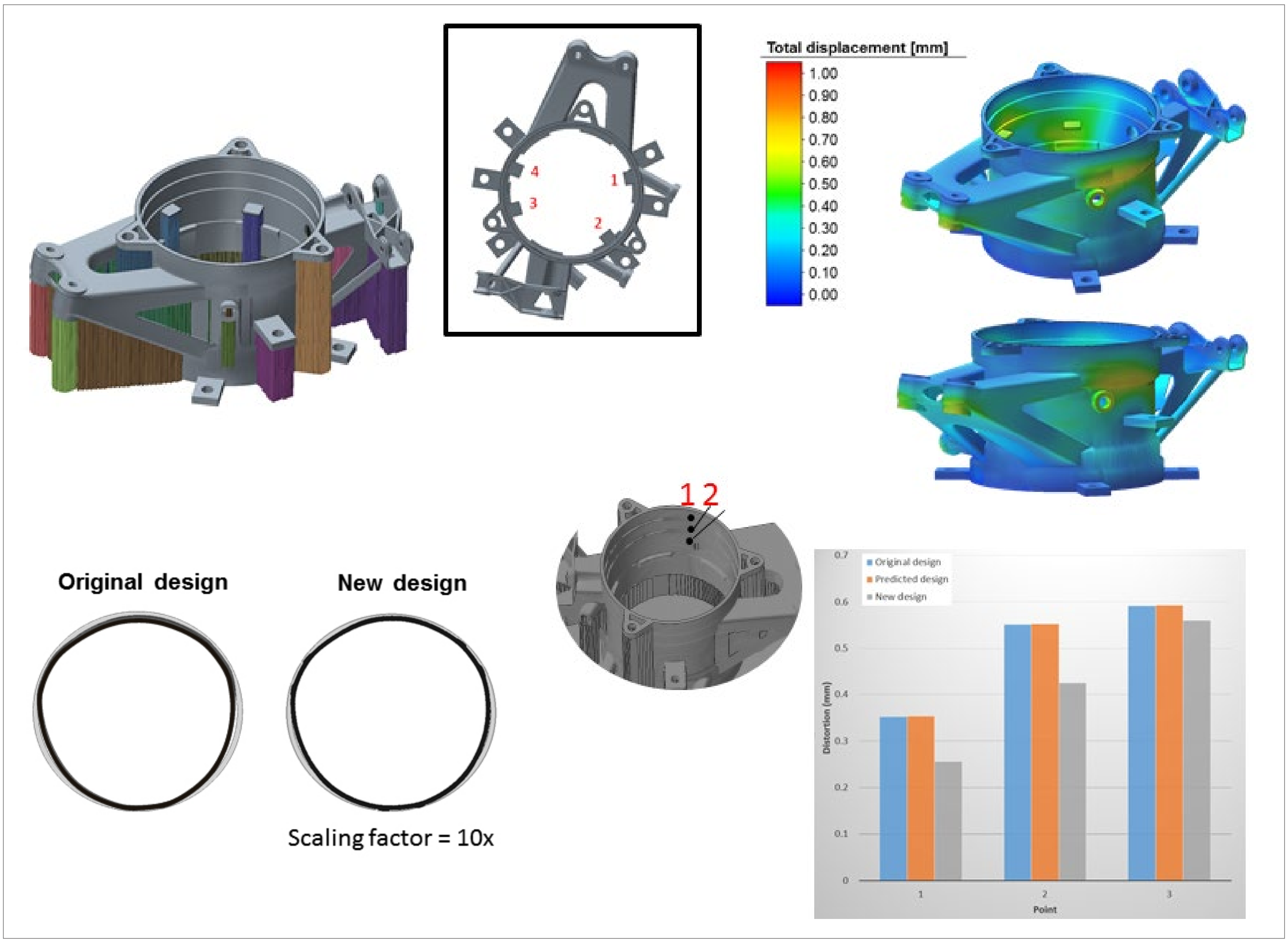


Figure 5: Simulation results of optimized part. A- New design, B- Distortion, C- Shape of the part with scaling factor 10x, D- Comparison of distortion values

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