Use of Simulation in Additive Manufacturing Process Chain of Thin-walled Automotive Parts

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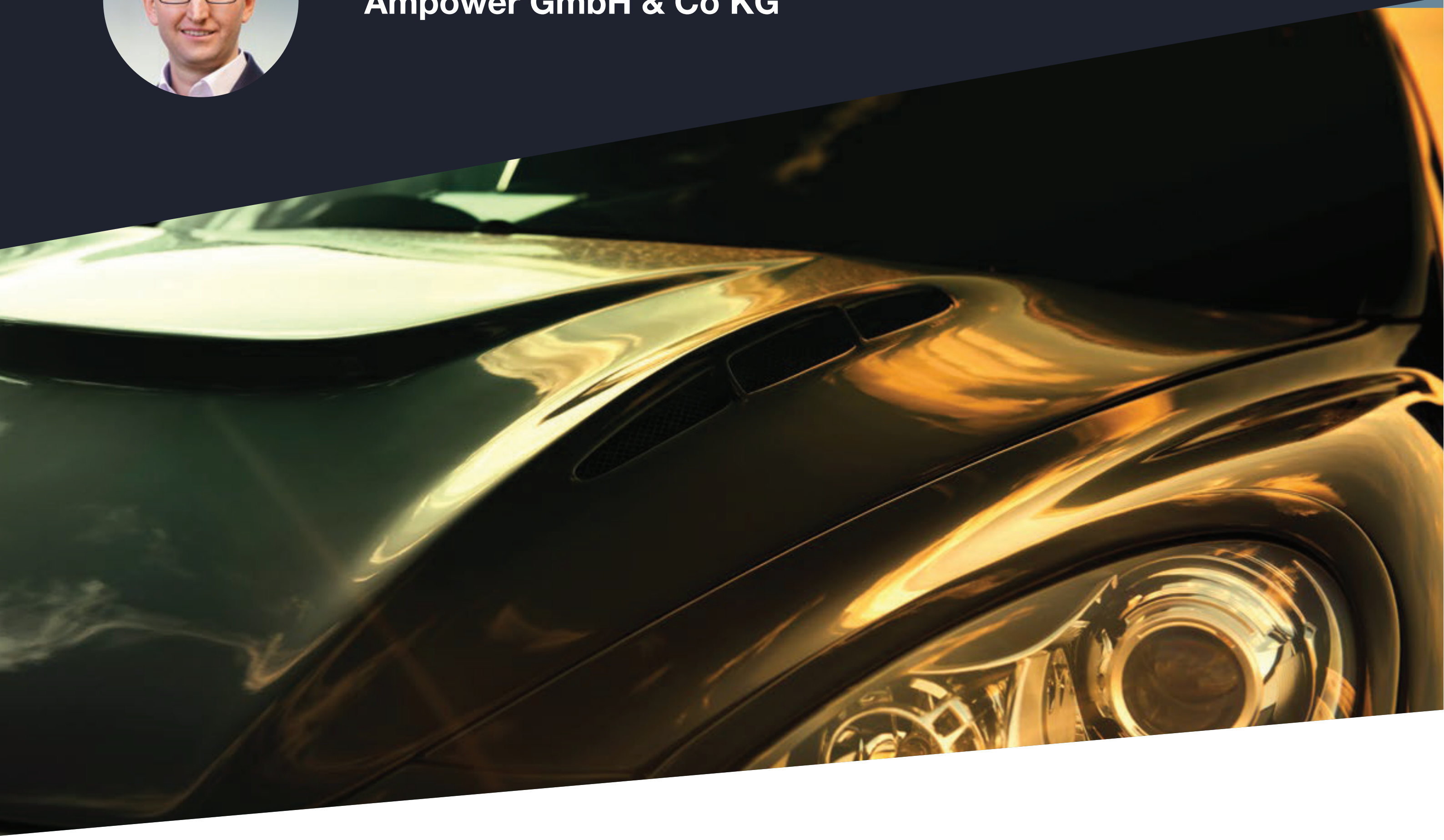

For more than 30 years, dozens of Additive Manufacturing (AM) technologies have been used for realizing prototyping applications. Over the past few years, AM was increasingly adopted for serial applications throughout industry, such as medical or aviation. The process of powder bed fusion with laser beam (PBF-L) of metals has the largest impact. It offers the highest degree of freedom of design and flexibility as well as excellent material properties.

Identifying automotive PBF-L applications becomes challenging when taking the industry's high demands regarding cost, quality and time into account. Because of the cost per volume of AM parts, currently only high priced, low volume vehicles or racing sports cars are targeted for application screening. In automotive production for mass markets, cost per part dominates the final decision on whether they will be manufactured additively or

Figure 1 Additive Manufacturing process chain

conventionally such as forging or casting. Manufacturers of high performance sports cars with limited quantitities up to approximately 5,000 units per year will be early adopters of AM. Ampower expects the largest potential in automotive applications to be in the power and drive train as well as the suspension system.

To analyze the status quo, Ampower conducted a study on Additive Manufacturing of a high-end automotive application - a tail pipe blend from a Porsche GT2 RS sports car and analyzed the complete AM process chain. Tail pipe blends are the visible part of the engine exhaustsystem. Optical requirements are high since the component reflects the engine's performance to the customer's eye. Conventionally, those blends are manufactured from stainless steel or titanium alloys. Two metal sheets formed by deep drawing are joined by a welding seam. Requirements for the mechanical properties are driven by vibration and corrosion which put high stress on the welding seam. Additionally, tail pipes are subject to major design iterations. This leads to remanufacturing of deep drawing tools at extremely high cost and typical lead times of over 12 months.

AM rarely make sense without exploiting the potential of redesign. A redesign has to consider not only specific parts but also all surrounding components, functions and assembly steps. For the present application, realized redesign advantages are short time to market due to tool-free manufacturing, increase of quality due to homogenous material properties, reduction of number of parts – and thus less assembly steps – and potential for customized design.

Figure 2 Re-designed, printed and post-processed tail pipe blend of sports car Porsche GT2 RS

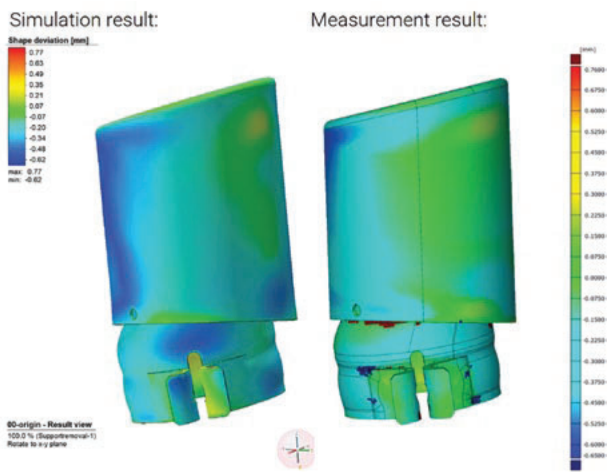

Figure 3 Results of simulation with Simufact Additive and computer tomography measurement of printed part

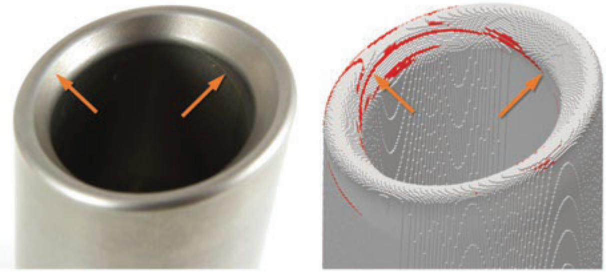

Figure 4 Detection of shrink lines with the new function inside Simufact Additive

The AM process chain used for production of the tail pipe blend is displayed in Figure 1. The final part manufactured with PBF-L using titanium alloy Ti-Al6-4V is shown in Figure 2 .

For complex free-form surfaces, optical 3D scanning, e. g. with Hexagon metrology devices, and computer tomography (CT) imaging are well suited methods to accurately measure the resulting geometry. In this study, the results of CT imaging were used to assess the feasibility of simulation tools that allow prediction and compensation of stress-induced deformations. The overall accuracy is mostly affected by distortion and part shrinkage from residual stress formed during the PBF-L process, where material cools at rates of several thousand Kelvin per second.

The simulation of the PBF-L process was conducted with Simufact Additive using the inherent strain model. The voxel size for discretizing the CAD data was set to 2 mm – the range of the wall thickness of the part. The simulation yielded a stress distribution and a prediction of the shape deformation. The comparison of the results of the simulation and the CT measurement are displayed in Figure 3. The conducted simulation shows a good match of absolute range of distortion, and the deviation is represented quite well.

Further analysis was done in collaboration with Simufact headquarters in Hamburg employing a brandnew function to detect specific part defects - so-called ‘shrink lines’. Such shrink lines are formed in layers where manufactured areas grow together, shrink during solidification and leave visible marks on the surface. These defects were visible at the upper region on the tail pipe blend after production as displayed in Figure 4. The part defects were correctly predicted by the simulation software and will allow for future compensation.

In conclusion, the study revelaed the feasibility for use of PBF-L process of thin-walled automotive parts. However, the relative high cost of the process will limit the use to high end applications with low volume. Simufact Additive predicted the deformation and shrinkage correctly and will allow improved process chains by enabling first time right production.

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About Ampower:

Ampower is the leading consultancy in the field of industrial Additive Manufacturing. Ampower advises their clients on strategic decisions by developing and analyzing market scenarios as well as compiling technology studies. On operational level, Ampower supports the introduction of Additive Manufacturing through targeted training program as well as identification and development of components suitable for production. Further services include the setup of quality management and support in qualification of internal and external machine capacity. The company is based in Hamburg, Germany. More about Ampower at am-power.de.

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