AeroSim – Laser Beam Melting Simulation tool for Aero Engine applications

Summary description of the project context and main objectives

Laser Beam Melting is an Additive Manufacturing (AM, often referred to as "3-D-printing") process that allows the production of full dense metal parts. The build-up is done in a layer wise fashion enabling the production of almost arbitrarily complex geometries. Thus, Laser Beam Melting offers significant advantages compared to conventional machining where manufacturing costs typically increase with the part's geometrical complexity. As a result, experts expect the market for systems, service and materials for AM to quadruple over the next 10 years. The simulation tool developed within the research project AeroSim strives to contribute to improve the Technology Readiness Level (TRL, source: ISO 16290:2013) of Additive Manufacturing and particularly Laser Beam Melting.

In May 2012, the Institute for Machine Tools and Industrial Management (*iwb*) of the Technische Universität München and the MTU Aero Engines AG started AeroSim with the aim to develop a simulation tool for Aero Engine applications. Figure 1 shows the simulation tools potential for assisting in the process of manufacturing parts without dimensional deviations.

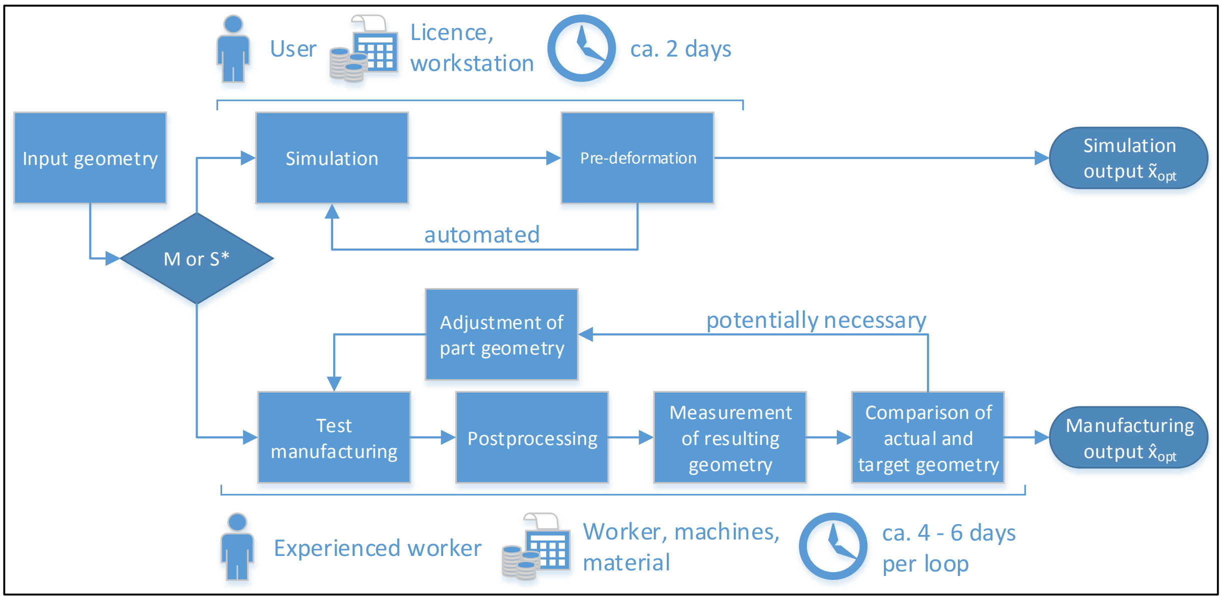

*Figure 1: Comparison of workflows for the manufacturing-based and the simulation-based process chain. Both share the initial geometry as input and an optimized geometry as output in order to manufacture a part without dimensional deviations in respect to the initial geometry. The necessary staff, the respective sources of expenses and the expected time frame are given (Source [1]). *M(achine-based) or S(imulation-based)*

The extensive work for manufacturing, measuring and manually optimizing the input geometry requires not only expertise and experience of the user as well as a longer processing time, but it is also dependent on costly machinery. With many companies maximizing machine occupancy, delays within the machine-based process chain are likely to occur. In contrast, user interaction within the presented automated optimization process chain is limited to providing the correct input files. Additionally, the simulation is less time consuming, e. g. the simulation for the sample part was completed in two days. Therefore Deliverable 5.1 is fulfilled. With the continuous improvement of simulation tools and the steady improvement of computer hardware, the time consumption of such simulations will further decrease. Lastly, simulations are expected to be less cost-intensive as their total costs are dominated by costs for licenses and normal PC hardware [1].

To guarantee maximum user benefit, suitable interfaces, among others with the additive manufacturing machine, are developed. The considered materials within AeroSim are nickel-base super alloy Inconel 718 and titanium-base super alloy Ti-6Al-4V.

Description of the work performed in project year 3 and main results achieved

A second, CAD-based process chain was developed in addition to the robust machine-data (CLI) based approach to improve dimensional accuracy of the results, thus increasing the usefulness of the simulated distortions. Additionally, an optimization system was developed to realize an iterative pre-deformation process.

For validation purposes, multiple parts were manufactured and compared to the results of corresponding simulations. Aside from a set of limited features like long overhanging structures, the agreement was found to be sufficient and Deliverable 5.2 is fulfilled. Furthermore, residual stress measurements were conducted at the Heinz-Maier-Leibnitz Neutron source in Garching/ Munich showing promising agreement to the respective simulations. MTU supported these validation efforts by providing results of hole drilling trials on the same samples. These results will be confirmed by x-ray diffraction trials in the near future and the entirety of the results is intended to be published in order to further the understanding of residual stresses in selective laser melting.

Last, both the CAD-based and the CLI-based process chain were adjusted to require minimal user interaction and tested extensively. The basic concepts of the model as well as the necessary knowledge to work with the developed simulation tool was taught in five training sessions at MTU Aero Engines facilities and documented in the corresponding training records. In summary, all milestones and deliverables were reached on time. To ensure the progress of the project (WP 1), regular meetings were held at MTU Aero Engines in Munich.

Sources:

[1] Bayerlein, F.; Zeller, C.; Zäh, M. F.; Weirather, J.; Wunderer, M.; Seidel, C.: " Improving cost effectiveness in additive manufacturing – Increasing dimensional accuracy in laser beam melting by means of a simulation-supported process chain“ (Hrsg.): Ansys Conference & 33. CADFEM Users' Meeting, Bremen, 2015.

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