Simulative Pre-Deformation with a Mesh-Independent Heat Source of Parts Produced through Laser Beam Melting

Daniel Wolf*, Christian Robl and Michael F. Zaeh

Institute for Machine Tools and Industrial Management (*iwb*)
Technical University of Munich
Boltzmannstr. 15, D-85748 Garching b. Muenchen, Germany
e-mail: daniel.wolf@iwb.mw.tum.de, web page: http://www.iwb.mw.tum.de

ABSTRACT

Additive Manufacturing (AM) enables the fabrication of complex, load path optimized designs with functional integration without additional cost. Laser Beam Melting (LBM) is an established AM process during which layers of metallic powder are selectively melted to generate a three-dimensional part.

Due to the high thermal gradients induced by the laser, the target geometry of the 3D component deforms during production. In addition to the geometrical deviation, high residual stresses occur during the manufacturing process. Both can lead to a process failure or insufficient part quality. In order to predict the described effects, an open source process simulation tool was developed at the *iwb* which simulates the manufacturing process and thus represents its digital twin.

During the model development, simplifications were made to shorten the computation time of the process simulation. Multiple physical layers were combined to one layer compound to increase the required minimum mesh size and to decrease the effort for thermal and mechanical calculations. The complexity of the thermal transient simulation was reduced by modeling the heat source as a flash exposure of the layer compounds. This heat source must be independent from the mesh size and heat load time to achieve physically correct results. Additionally, a non-layered mesh was employed to allow the simulation of complex geometries.

This paper presents a process simulation approach based on the Finite Element Method that calculates the deformation of the component independently from the mesh size and the layered compound height. Furthermore, the developed simulation tool offers the possibility to optimize the dimensional accuracy. For this purpose, an algorithm for iterative pre-deformation of the initial geometry was developed in order to counteract the process-related deformation. The pre-deformation algorithm and the developed heat source were validated by comparing the simulated and measured deformations of 45 turbine blades (18 nominal and 27 pre-deformed) manufactured on an EOS M-400. The evaluation showed that the dimensional accuracy of the pre-deformed turbine blades could be significantly improved by using the simulation tool.