The Calibration For DED Process Simulation On Part-scale For Ti6Al4V

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Abstract

Simulating Directed Energy Deposition (DED) processes can be a complex task, especially when working with high-performance materials like Ti6Al4V alloy. However, accurate finite element models require calibrated thermal and mechanical parameters, which can be challenging to obtain. Then with an accurate model a prediction of the stresses, strains and deformation can be made of any part produced with DED. This research investigates multiple calibration methods for DED process simulation of Ti6Al4V alloy, focusing on thermal and mechanical parameter extraction. Two calibration approaches are investigated: manual tuning and machine learning-based optimization. Additionally, this study aims to contribute to the standardization of the calibration process, ensuring consistency and reproducibility across different simulations and materials. The study identifies five key parameters: absorption, convection during printing convection during cooldown, emissivity of the printed part and emissivity the base plate. A custom-designed experimental setup enables printing of five parts with temperature measurements at three locations, supplemented by thermal imaging using an infrared camera. The infrared camera data is used to calibrate the emissivity of the printed part and base plate, accounting for surface roughness effects on radiative heat transfer. This set-up creates the possibility to print the thermal calibration part, the mechanical calibration part and a validation part in one job. Taking standardization into account a reusable plate in which the thermocouples are mounted is designed for the set-up. This plate guarantees that the thermal measurements will be done at the same location for each future calibration. Thus improving the consistency of the calibration process. The calibrated parameters are then used in a thermo-mechanical simulation setup using the Additive Manufacturing (AM) plugin in Abaqus. The simulation consists of two parts: thermal and mechanical. During the thermal simulation, elements are activated over time and given a heat input corresponding to the laser power. The absorption coefficient determines how much of this heat input is absorbed by a certain element, resulting in an increase of temperature. This creates a temperature gradient over time of the printed part. Once the temperatures during the printing process are known, these results are used as input for the mechanical simulation. The mechanical simulation consists of three steps: printing, cooldown, and declamp. The simulation results are compared to experimental data in the form of temperature measurements and deformation of the part, allowing for the calibration of the parameters. Our results show that both calibration methods can accurately predict thermal and mechanical behavior, but machine learning-based optimization outperforms manual tuning in terms of time required for the calibration. Although it does require more simulation results to perform. Automation of that process is possible and thus the effort the calibration costs is reduced. This study highlights the importance of accurate calibration of parameters such as absorption, convection during printing and cooldown, and emissivity of the printed part and base plate. Lastly it will be discussed how our findings can be applied to improve DED simulation for other materials, and how standardization of the calibration process can facilitate the development of more accurate and reliable simulations across different materials and applications.

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