The 8th European Congress on Computational Methods in Applied Sciences and Engineering
ECCOMAS Congress 2022
5 – 9 June 2022, Oslo, Norway

Investigation of parameter-dependent material characteristics of additively manufactured specimens for data-driven part optimization

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Key Words: *laser powder bed fusion, data-driven optimization, green computing, multi-physical optimization, tensile strength, temperature gradient, porosity, microstructure*

In the field of Laser Powder Bed Fusion (LPBF), predictive simulation models are not yet available due to the modeling complexity of physical phenomena interacting at different scales [1]. Furthermore, the simulation of even simple structures can lead to high computing costs (model development, CPU, computing time) which hinders the economic interest of a pure simulation approach [2]. The high computing times in turn correlate with a certain CO2 footprint related to the energy consumption, cooling systems, etc. [3].

Another approach of investigating the material characteristics of a printed structure is to involve experimental data as in the spirit of Stainier et al. [4]. Here, the modeling and simulation of all the complex physical phenomena is enriched by data from practical experiments. Our data assimilation approach is illustrated by a test case in which a Design of Experiments (DoE) is executed. Within the DoE, which includes 17 different parameter sets, 5 sets of cylindrical specimens (StrengthAl) were fabricated via Direct Metal Laser Sintering (DMLS). The material characteristics (porosity, tensile strength, Young's modulus and temperature gradient) were investigated using a Scanning Electron Microscope (SEM), a tensile testing machine (Zwick Roell Z020) and a self-designed test setup for measuring thermal properties.

The test results, which were clustered using the k-mean clustering algorithm, show a clear correlation between the modified parameter settings (laser power, laser speed, hatch distance and layer thickness) and the afore mentioned material characteristics. It was also recognized that the printing parameters lead to different kinds of microstructures (brittle, ductile).

The experimental approach represents the first step within the development of design guidelines that could enable multi-physical part optimization without complex simulation models.

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