Prediction of eigenstrains and residual stresses in additive manufactured parts using the inherent strain method

C. Burkhardt*, P. Steinmann* and J. Mergheim*

* Institute of Applied Mechanics
Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany
e-mail: christian.burkhardt@fau.de

ABSTRACT

Additive manufacturing offers the ability to design parts more freely and allows for complex geometries. In selective beam melting, parts are built in a layer-by-layer fashion by locally melting and fusing metallic or polymer powder to bulk material. For metallic materials the energy input can either be due to a laser or due to an electron beam.

There are large differences in the length and time scales, which range from micrometers for layerheights to even kilometers for scanpath-lengths and from microseconds for beam exposure times to days for process times. Therefore, process simulations of whole parts are computationally expensive. High fidelity models that capture the melt pool depth and width on a microscopic level are not suited for the simulation of whole parts. For that reason reduction methods like preintegrating the heat input in time as shown in [1] or [2] are used, which lead to huge reductions of the computational cost, especially for polymer materials. But this approch is limited in case of materials due to their higher thermal conductivity. Other less detailed process models are required to compute global quantities such as residual stresses and distortions. One of these lower fidelity approaches is the inherent strain method, which is widely used in the welding community, and was adopted to additive manufacturing processes [3]. In this approach, the simplified assumption is made, that all scanned areas, experience the same thermal history and therefore the same mechanical strains. The influence of the scanning strategy can only be partially captured and the results of the inherent strain method are critically discussed in literature [4].

In this contribution the inherent strain method is used to determine the warpage and residual stresses of additive manufactured parts. An extension of the method is presented to better understand the influence of the scanning strategy. The numerical results for different geometries, such as the symmetrical twin-cantilever beam structure, which is well known in the context of the inherent strain method, are critically investigated. The simulated deflections are compared to experimental results.

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