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Validation of the Temperature History during Extrusion Based Additive Manufacturing

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Additive manufacturing (AM) is considered as a key technology for the efficient production of individualized components. The technique enables the tool-less production of complex geometries and designs that could not be realized cost-effectively with conventional manufacturing methods. The focus of the presentation is on the Fused Filament Fabrication (FFF), where a thermoplastic filament is extruded trough a nozzle. The material is deposited layer by layer until the final part is build. Thereby, high temperature gradients occur within the part when the hot material is deposited on the lower layers. During the printing process the lower layers are reheated several times so that the material properties are influenced even after the deposition has been made. The thermal history has major effects on crucial material properties such as the degree of crystallization or viscosity. An insufficient viscosity can lead to a weak bonding and reduced strengths between adjacent layers. An inadequate degree of crystallization influences both the structural properties such as the stiffness or the degree of bonding and the dimensional accuracy due to subsequent shrinkage effects. Additionally, the temperature gradients cause residual stresses which are partly relaxed to varying part deformations. The remaining stresses can lead to premature failures. To achieve a high and repeatable part quality as well as a low scatter in the final part dimension an, in-depth process understanding is required considering the underlying material-process-part-interactions. In order to analyse these complex Multiphysics processes, manufacturing process simulations are a suitable method.
A main requirement for the numerical analysis of AM processes is the calculation of the thermal history as accurately as possible. The objective of this work is, therefore, to evaluate the prediction accuracy of currently availableAM process simulation tools. For this purpose, atoolpath-based AM process simulation of a cuboid is performed in order to calculate the transient temperature fields using the Abaqus AM plug-in from Dassault Systèmes. The cuboid made of PETG is printed with a Prusa i3 MK3. In order to monitor the temperature history during the printing process very thin thermocouples (0.25mm) are integrated in the centreof the part. The machine code (gcode) is transferred to the Abaqus specific data format and the transient temperature fields are predicted in dependency on the thermal boundary conditions. Therefore, an efficient progressive element activation technique is used. Finally, the predicted temperatures are compared to the measurements.The prediction accuracy is evaluated, deviations are discussed and reviewed by further experiments.