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High order embedded domain methods: thermo-mechanical simulation of additive manufacturing processes

Ali Özcan[1,*], Stefan Kollmannsberger[1] and Ernst Rank[1]
[1] Computation in Engineering, Technische Universität Mnchen, Arcisstrae 21, D-80290 Mnchen,
{oezcan, kollmannsberger, rank}@tum.de

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ABSTRACT

This contribution will focus on the simulation of thermo-mechanical problems on growing domains, as they appear e.g. in the computational analysis of additive manufacturing.

Additive manufacturing is a production process in which artefacts are produced successively by generating layers of material of different shapes and often also of varying material properties. Until today, dozens of different additive manufacturing processes have been suggested, see e.g. [1] for a review. A large cluster of processes is formed by Laser Metal Sintering (SLM). Herein, a highly focused laser beam selectively melts metal powder. After cooling, these regions harden to almost fully dense metal. The computational modelling of these processes clearly is very demanding both w.r.t. the involved physics as well as w.r.t. the necessary discretization. The latter challenge mainly stems from the broad range of scales. In space the scales vary from the size of the melt front, where the phase-transformation from powder to liquid to solid takes place ($\sim 10\ \mu$m), to the size of the laser beam itself ($\sim 100\ \mu$m) and the lenght of the total track of the laser beam (~ 10 km) to produce a finished artefact (~ 10 cm^3). The discretization should be able to handle the growing nature of the domain, since over time new layers of powder material are added.

This contribution will present a first attempt to create a computational framework aiming to resolve these discretizational challenges. In the spirit of the Finite Cell Method [2], the treatment of the field variables, such as temperatures or thermal stresses are strictly seperated from the material state, i.e. an indicator function, if at a certain time and location material exists or not. This transient embedded domain approach eliminates the need for a boundary conforming mesh and facilitates representation of the growing domain. In order to discretize the field variables and bridge the scales, the hierarchic high-order scheme described in [3] is utilized. Finally three-dimensional examples demonstrating capabilities and limitations of this new discretizational approach are presented.

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