

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

Ali Özcan^{1,*}, Stefan Kollmannsberger¹ and Ernst Rank¹

¹ Computation in Engineering, Technische Universität München, Arcisstraße 21, D-80290 München, {oezcan, kollmannsberger, rank}@tum.de

Key words: Finite Cell Method, Multiphysics, Applications.

ABSTRACT

This contribution will focus on the simulation of thermo-mechanical problems on growing domains, for example, 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 ($10 \mu\text{m}$), to the size of the laser beam itself ($100 \mu\text{m}$) and finally to the finished artefact (10cm). 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], which strictly separates the treatment of the field variables, such as temperatures, from the coefficients, such as material states. This eliminates the need for a boundary conforming mesh which facilitates to represent 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.

REFERENCES

- [1] Wohler, B. (2013). Wohlers Report 2014: Additive Manufacturing and 3D Printing State of the Industry. <http://wohlersassociates.com/2014report.htm>.
- [2] Düster, A., Parvizian, J., Yang, Z., and Rank, E. (2008). The finite cell method for three-dimensional problems of solid mechanics. *Computer Methods in Applied Mechanics and Engineering*, 197:3768-3782.

- [3] Zander, N.; Bog, T.; Kollmannsberger, S.; Schillinger, D.; Rank, E (2015). Multi-Level *hp*-Adaptivity: High-Order Mesh Adaptivity without the Difficulties of Constraining Hanging Nodes, *Computational Mechanics*, 55:499-517, DOI: 10.1007/s00466-014-1118-x