A discrete element method framework for simulating multi-material additive manufacturing processes

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ABSTRACT

Multi-Material Additive Manufacturing (MMAM) opens up a wide range of new applications and possibilities. However, simulating Additive Manufacturing (AM) processes with the Finite Element Method (FEM) is still far from optimal. The layer-wise AM processes, as well as the large variations in time- and length scales, create difficulties for simulating with FEM. The flexibility, in particular freedom of geometry and multi-material interfaces, of a Discrete Element Method (DEM) seems to provide various advantages compared to FEM when simulating AM processes [1, 2, 3].

In this presentation the set-up of a DEM framework for different AM processes is shown. The feasibility of DEM when simulating AM is assessed as it typically is a computationally expensive method and requires many input parameters. It is examined whether DEM solves the problems encountered by FEM, such as homogenization, complex constitutive models and addition of new material. The obtained increase in resolution of DEM compared to FEM allows for the AM process to be studied in detail, especially multi-material interfaces.

The DEM framework is set up as follows [1]. First a layer of particles is added. The subsequent movement of the energy source (heat or light) is obtained from a GCode input file. The kinematics are captured by a contact force dependent on the overlap between particles or a bond force dependent on the difference with the equilibrium bond length. Heat transfer is modelled by conduction dependent on the contact area. Thermo-mechanical coupling is governed by thermal expansion of the radius of particles and multiple temperature dependent parameters. The procedure can be repeated for many layers to simulate the manufacturing of a small component.

Optimization is done in various ways beginning with a cell-contact-detection-algorithm. The domain is divided into cells, so only particles in neighbouring cells have to be checked for contact. Further optimization is possible by parallel computing and switching groups of discrete elements with finite elements, which decreases the amount of degrees of freedom. Implicit integration can be used to increase time-step sizes at the expanse of some computation time compared to explicit integration.

As a primary test-case, multi-material Selective Laser Sintering (SLS) is used to demonstrate the capabilities of the DEM framework, which shows the full temperature and stress field for every time step during and as a result of the printing process. The framework has no problems simulating different complex geometries and interfaces between two different materials can be studied in detail.

REFERENCES

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