Method for the Simulative Determination of the Effective Mechanical Material Parameters of Support Structures in Laser Beam Melting

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ABSTRACT

Additive Manufacturing (AM) enables the fabrication of complex, load path optimized designs with functional integration without additional cost. Laser Beam Melting (LBM) is an established AM process during which layers of metallic powder are selectively melted to generate the 3D part. Geometrical features (e.g. overhang surfaces with a pitch angle below a powder-dependent critical angle) are prone to sink into the powder resulting in poor part quality or failure of the process [1]. In order to prevent this, support structures are placed below these critical areas.

Mechanical failure of support structures during the LBM process can result in abortion of the build process or reduced part quality. This can be avoided by maximizing the support structures volume or density. A minimization of the mass of these structures is desired, because they are non-recyclable waste material and have to be removed from the built part after the LBM process [2].

To balance these conflicting requirements it is important to know the physical behavior of support structures during the build job preparation. The missing knowledge about the mechanical and thermal behavior of support structures currently prevents its effective use during LBM.

In this work, an automated and efficient simulation method for determination of the effective mechanical material parameters of support structures with periodic unit cells (i. e. block support) is presented. A parameterized model of the unit cell is generated and discretized using the Finite Element Method (FEM). Periodic boundary conditions are applied to the interfaces of the FEM discretization to guarantee a conforming behavior of the unit cell. Virtual testing with six independent load cases (three tensile tests, three shear tests) is performed and the resulting mechanical behavior (strains, stresses) is homogenized over the unit cell volume. These averaged strains and stresses of the six load cases are combined in a linear system of equations and solved for the mechanical parameters (Young's modulus, Shear modulus, Poisson's ratio) of the unit cell. As a result, the effective mechanical material parameters of a unit cell with given geometry is returned.

This method was applied to determine the mechanical parameters for quadratic block supports with varying grid spacing and wall thickness. Using the Least Square Method an analytical description of the mechanical parameters as a function of the geometrical input parameters could be determined for all mechanical parameters.

This simulation method can be extended to support geometries with arbitrary unit cells. Thus, a database for the simulation results of individual geometries can be generated and used for the mechanical design of support structures for LBM. The analytical description of the effective mechanical material properties of support structures with quadratic unit cells enables the support structure design without a simulation.

REFERENCES

[1] Calignano, F. Design optimization of supports for overhanging structures in aluminum and titanium alloys by selective laser melting. *Materials & Design* (2014) **64**:203-213.

[2] Krol, T.A., Zaeh, M.F., Seidel, C. Optimization of support in metal-based additive manufacturing by means of finite element models, In Solid Freeform Fabrication Symposium (2012) 707-718.