Micromechanical Modelling of Additively Manufactured Columnar IN 718

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ABSTRACT

Selective electron beam melting represents an additive manufacturing process where complex parts are built in a layer-wise manner using metal powders. The powder is fused selectively by the energy of an electron beam guided by electromagnetic fields. This so called electromagnetic lens allows for very fast deflection and thus very high beam velocities and different scan strategies. By using these scan strategies it is possible to tailor the resulting mesostructure in the material which may range from a columnar to an equiaxed grain structure. For altered grain structures, different macroscopic mechanical properties are expected. Long grains oriented along the building direction cause highly anisotropic behaviour. In contrast, a uniform grain structure results in isotropic mechanical behaviour. Furthermore, different orientations of the unit cells, the effects of grain size and boundaries influence the macroscopic mechanical properties. The parameter identification for material models considering these effects is experimentally expensive. Thus, isotropic material models are often used for process simulations, simulations of parts or topology optimizations. To overcome this limitation a mesoscopic model has been developed and validated [1] which is used to identify the parameters of a quartic yield function.

The Finite Element Method together with grain structures from numerical grain growth simulations are used to simulate columnar grained IN 718, a face-centred-cubic nickel base alloy. On the mesoscale, the mechanical behaviour is modelled using a gradient-enhanced crystal-plasticity model [2], allowing for relative misorientations on the grain boundaries [3]. Computational homogenization and macroscopic experimental data are used to inversely identify elastic and plastic meso- and microscopic mechanical parameters. With this model at hand the macroscopic yield locus in all biaxial sub-surfaces of the six dimensional stress space is identified as a surface of constant dissipation and simulated for different values of dissipation. A quartic yield function similar to [4] is fitted to the obtained results. Potential fields of application are topology optimization extended with information regarding preferred directions of the anisotropic material, which allows aligning these orientations based on the requirements on the parts or simulations of the process and parts.

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