

Micro-mechanical modelling of additively manufactured 316L stainless steel

A. Biswas^a, M. Prasad^a, N. Vajragupta^a, H. ul Hassan^a, F. Brenne^b, T. Niendorf^b
A. Hartmaier^a,

^a Interdisciplinary Centre for Advanced Materials Simulation, Ruhr-Universität Bochum
Universitätsstr. 150, 44801 Bochum, Germany

^b Institut für Werkstofftechnik / Metallische Werkstoffe, Universität Kassel
Mönchebergstraße 3, D-34125 Kassel, Germany

Additive manufacturing (AM) has recently come into focus for manufacturing of complex metallic structures. Selective laser melting (SLM) is an AM technique employing metal powders as basis. Microstructure evolution of structures manufactured by SLM is strongly affected by process parameters. Consequently, grain orientations may rapidly change during the manufacturing process due locally differing thermal history. The resultant material can show highly textured, columnar polycrystalline microstructure as well as equiaxed grains. In case of columnar grain structure, the tensile test results of materials reveal anisotropic behavior. In light of this dependence of material behavior on geometry and texture, it is vital to produce a synthetic microstructure, which closely represents the morphology of the real microstructure. Currently available non-local crystal plasticity models are incapable of modeling microstructural anisotropy, therefore it is imperative to include effects like direction dependent Hall-Petch to predict such anisotropy.

This work aims at developing a strategy for micromechanical modeling of such materials to predict the mechanical properties. The morphology of the polycrystalline microstructure is approximated by radical Voronoi tessellations. An efficient packing algorithm is used to pack the elongated grains with overlapping spheres for tessellation purposes only. By exploiting the advantages of both packing algorithm and the radical Voronoi tessellation, an efficient microstructure is generated. The extracted orientation distribution from EBSD characterization consists of large number of orientations, which have to be systematically reduced to closely represent the real texture. The hybrid integer approximation method has been used in this regard. Furthermore, during the deformation of polycrystals, pronounced strain gradients may occur at grain boundaries between grains, whose misorientations lead to a large mismatch in their deformation behavior. Hence, to closely represent the real microstructure not only the orientation distribution, but also the misorientation distribution has been included into the synthetic microstructure. Finally, numerical simulations of uniaxial tensile testing are performed for different loading directions and the results are compared with experimental data.

References

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