Anisotropic Polycrystal Plasticity due to Microstructural Heterogeneity in Additively Manufactured Metallic Parts: Experimental Investigation and Crystal Plasticity Simulation

S. A. H. Motaman *, P. Köhnen, C. Haase

Steel Institute, RWTH Aachen University, Intzestr. 1, 52072 Aachen, Germany
Web page: www.iehk.rwth-aachen.de
*e-mail: Seyedamirhossein.Motaman@iehk.rwth-aachen.de

ABSTRACT

Metal additive manufacturing (AM) has strongly gained scientific and industrial importance during the last decades due to offering geometrical flexibility and increased reliability of parts, as well as reduced equipment costs [1]. Additively manufactured metallic products are substantially different in microstructure from those that have been conventionally produced by traditional casting, thermomechanical treatment and subtractive manufacturing processes. Characterization studies reveal that the microstructures of as-built additively manufactured metallic components contain strong texture, highly inhomogeneous grain morphology, multiscale heterogeneities, relatively high content of pre-existing defects and elemental segregation [2]. The disparate highly anisotropic mechanical response under viscoplastic deformation observed in AM metals, compared to their conventionally manufactured counterparts, lies in the aforementioned inherent microstructural differences. In this study, we have focused on the application of laser-powder bed fusion (L-PBF) for processing high-manganese twinning-induced plasticity (TWIP) steel. The resultant as-built microstructure is carefully characterized by electron backscatter diffraction (EBSD) and X-ray diffraction (XRD) techniques. For fully exploiting the metal additive manufacturing potential, understanding the microstructure of additively manufactured parts and its connection with mechanical properties is essential. The mechanical response of AM parts under viscoplastic deformation is highly complex and its simulation requires advanced constitutive modeling and numerical methods. In the present study, we have resorted to full field crystal plasticity method using a spectral solver combined with physics-based constitutive modeling [3] in order to simulate the anisotropic strain hardening behavior of additively manufactured TWIP steel. The influence of different process-induced microstructural heterogeneity aspects on its macroscopic plastic flow behavior has been thoroughly investigated.

REFERENCES

GRAPHICAL ABSTRACT

Figure: Simulated distributions of equivalent strain, dislocation density, twin fraction in the microstructure of deformed (10% strained uniaxially along the building direction) additively manufactured (L-PBF) TWIP steel (X30MnAl22-1).