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Influence of Microstructure on Deformation Mechanisms and Mechanical Properties of Additively Manufactured Steel

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Abstract : Correlations between microstructure, deformation mechanisms, and mechanical properties in additively manufactured 316L steel components have been investigated. Mechanical properties in the vertical direction (building direction) and in the horizontal direction (in plane directions) are markedly different. Vertically built specimens show lower yield stress but higher elongation than their horizontally built counterparts. Microscopic observations by electron back scattered diffraction (EBSD) for both build orientations reveal a strong [110] fiber texture in the build direction but different grain morphologies. These microstructures are used as input in subsequent crystal plasticity numerical simulations to understand their influence on the deformation mechanisms and the mechanical properties. Mean field simulations using a visco plastic self consistent (VPSC) model were carried out first but did not give results consistent with the tensile test experiments. A more detailed full-field model had to be used based on the Visco Plastic Fast Fourier Transform (VPFTT) method. A more accurate microstructure description was then input to the simulation model, where thin vertical regions of smaller grains were also taken into account. It turned out that these small grain clusters were responsible for the discrepancies in yield stress and hardening. Texture and morphology have a strong effect on mechanical properties. The different mechanical behaviors between vertically and horizontally printed specimens could be explained by means of numerical full-field crystal plasticity simulations, and the presence of thin clusters of smaller grains was shown to play a central role in the deformation mechanisms.

Keywords : additive manufacturing, crystal plasticity, full-field simulations, mean-field simulations, texture
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