Incorporating surface roughness into numerical modeling for predicting fatigue properties of L-PBF AlSi10Mg specimens

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Abstract: Laser powder bed fusion (L-PBF) is a popular additive manufacturing method for fabricating metal parts with complex geometries. However, one of the primary setbacks lies in the surface quality of the as-built components. Poor surface quality influences the dynamic fatigue properties of L-PBF parts. Experimental investigation of fatigue properties is time-intensive and expensive. Numerical modeling enables rapid evaluation of fatigue properties and sheds insight into the impact of surface roughness on those properties. In this work, a numerical modeling framework is developed that considers the influence of actual surface roughness on fatigue properties. To calibrate and validate the numerical modeling framework, mechanical investigations of miniature AlSi10Mg specimens are conducted in a custom-built tensile-fatigue testing apparatus. At first, the tensile properties are evaluated to test the reliability of the apparatus. The tensile property evaluation is followed by the fatigue investigation of two sets of specimens: FS1 to FS5 for calibration of the numerical model and VFS1 to VFS3 for validation of the model. The development of the numerical framework includes X-ray computed tomography (CT) of the specimen followed by reconstruction of the 3D geometry from stacked cross-sectional CT images. Thereafter, the geometry is meshed and utilized in finite element modeling. The numerical results of fatigue life and failure locations of VFS1 to VFS3 are compared with the experimental observations. The comparison demonstrates that the numerical results are within 5% of the experimental observations. In addition, the location of maximum strain localization in numerical modeling matches the critical surface feature location obtained from surface roughness analysis.