Quantifying Damage Evolution During In-situ Loading of Additively Manufactured 316L Stainless Steel Using High Energy X-rays

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The evolution of damage, texture, and strain in additive manufactured (AM) 316L stainless steel produced via laser powder bed fusion was investigated during in-situ tensile loading using high energy X-rays. Synchrotron X-ray computed tomography (XCT) measurements were performed to determine the initial porosity and monitor the evolution of porosity during tensile loading as well as detect the initiation and growth of voids from pre-existing pore defects in the specimens. The as-built tensile specimens had a cross-sectional area of 1 mm^2, which was chosen in order to understand damage behavior in thin-walled structures. Far-field X-ray diffraction measurements were performed to quantify crystallographic texture and the distribution of internal elastic strains during loading. The initial texture from the AM build process had a weak {220} texture aligned parallel to the build direction. As a result of tensile deformation, a strong {111} + {200} double fiber texture develops at high tensile strains and remains until fracture. XCT results confirmed that the inhomogeneous distribution of porosity near the surface played a significant role in damage evolution during tensile loading where voids and cracks initiated at pre-existing pores located within the contour zone. These pores were found to have asymmetric or irregular morphology. At high tensile strains, the massive accumulation of internal damage at these pores eventually connected to the surface reducing the ductility in these thin-walled AM samples and resulting in final failure.

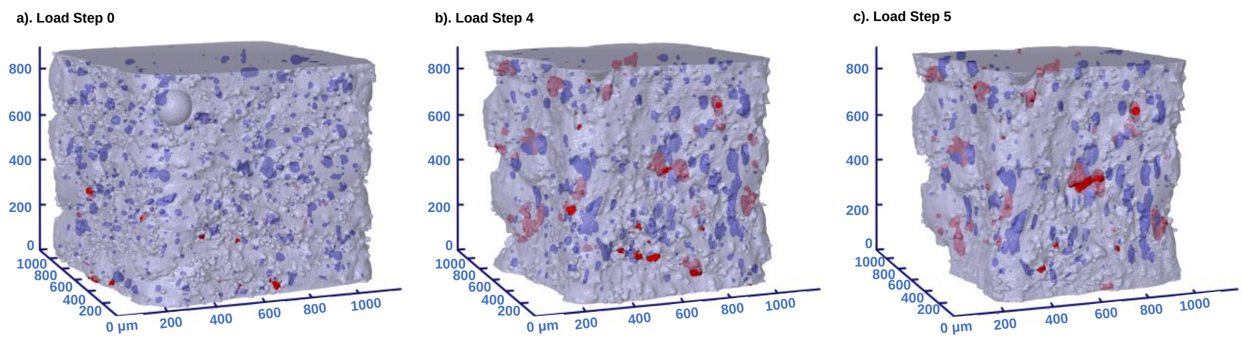

Figure 1: Three-dimensional reconstructed pore distribution for sample 2 at a). Load Step 0 (as-built condition), b). Load Step 4, and c). Load Step 5 (final failure).