Orientation-Dependent Yield Surface Evolution and Anisotropic Plasticity in LPBF-Manufactured SS316L

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The rapid adoption of laser powder bed fusion (LPBF) for stainless steel 316L (SS316L) components necessitates a deeper understanding of anisotropic plasticity under complex loading conditions [1]. This study presents a comprehensive experimental investigation of the initial and evolving yield surfaces of LPBF-fabricated SS316L, explicitly addressing the influence of printing orientation and plastic pre-deformation. Tubular specimens were manufactured in three orientations (XY, ZX45 and Z) and subjected to multiaxial loading using a single-specimen probing methodology, enabling efficient and precise yield surface characterization in axial–shear stress space.

Yield surfaces were determined using Szczepiński anisotropic yield criterion at initial state and subsequently tracked after controlled tensile plastic pre-strain equal to 0.35%, 0.5% and 0.8%. The results reveal pronounced anisotropy in LPBF specimens, strongly governed by build orientation. The Z-oriented samples exhibit reduced yield strength and enhanced softening in yield loci, while XY and ZX45 orientations demonstrate comparatively higher yield strength under selected loading paths. Additionally, specimens exhibit orientation-dependent yield surface translation and rotation, indicating complex interactions between strain-induced hardening/softening mechanisms and inherent microstructural anisotropy [2].

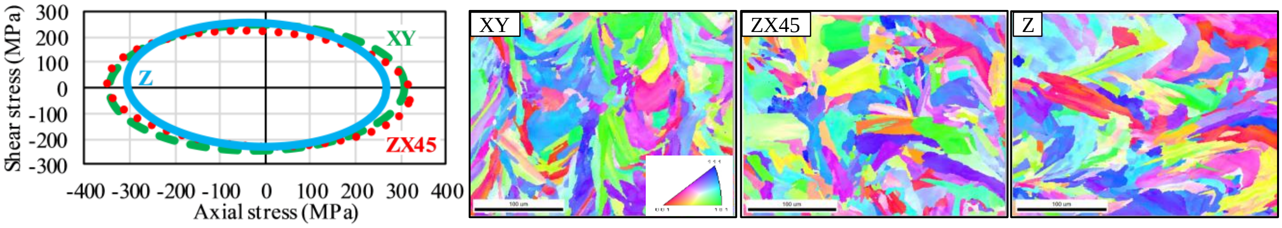

Figure 1. Initial yield surfaces at 10με offset definition of yield and IPF maps of three printing orientations.

Microstructural analysis using electron backscatter diffraction (EBSD) establishes a strong correlation between grain morphology and mechanical anisotropy. Columnar grains aligned along the build direction in Z-oriented samples promote directional deformation and strain localization, whereas more equiaxed structures in XY and ZX orientations contribute to improved mechanical uniformity. Despite weak crystallographic texture, melt pool geometry and interlayer boundaries emerge as primary drivers of anisotropic plastic response.

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[1] V.P. Dubey, D. Przygucka, M. Pawlik, Z.L. Kowalewski, P. Wood and M. Kopec, *Materials Today Communications* **50**, 114531, 2026. https://doi.org/10.1016/j.mtcomm.2025.114531

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