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EFFECT OF PLASTIC PRE-STRAIN ON THE YIELD SURFACE OF LPBF-MANUFACTURED STAINLESS STEEL 316L

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1. Introduction

In recent years, additive manufacturing (AM) offers a revolutionary approach for fabricating complex-shaped, high-performance components with minimal material waste and post processing through a layer-by-layer deposition of materials. Stainless steel 316L (SS316L) belongs to the materials of an austenitic structure. It is widely used in such industries as aerospace, medical, and energy due to its exceptional corrosion resistance, biocompatibility, and mechanical properties. Additionally, its low thermal conductivity, high melting point, and other distinctive attributes make it well-suited for additive manufacturing [1]. The mechanical characterization is still primarily performed by means of uniaxial testing methods, whereas, it provides limited data concerning the mechanical strength and damage of materials in a single direction which does not simulate into real-world multiaxial stress conditions [2]. To fully understand material's behaviour, including initial texture or anisotropy, yield surface identification in the biaxial or triaxial stress space is important.

Therefore, in this research the yield surface approach in the biaxial stress space based on the offset yield point definition was applied to assess the variation of mechanical properties in the as-printed and pre-deformed material. An experimental investigation was conducted to understand the physical mechanism accountable for plastic deformation caused by monotonic tension in AM SS316L in vertical build orientation.

2. Materials and methods

The SS316L was additively manufactured using the Renishaw AM 250 system (Laser Powder Bed Fusion technology) with powder feedstock. The round tubes were printed in Z – vertical orientation following the parameters in Table 1. After printing, specimens underwent stress relief at 470°C for 6 hours while still attached to the build plate, then were detached via wire cutting and then machined into tubular specimens.

The mechanical testing was performed on the MTS 858 biaxial testing machine at room temperature, with Vishay 120Ω strain gauges bonded on the tubular specimens to measure and control axial, shear and hoop strains. Tensile pre-deformation was applied at 0.35%, 0.5%, and 0.8% plastic strain. After reaching each pre-strain value, specimen was linearly unloaded to zero stress and then yield points were determined using sequential probes in the plane stress state, where strain-controlled loading was applied until a limited plastic strain (0.0015%) was reached, followed by stress-controlled unloading. The procedure was performed along 17 strain paths (0° to 360° in increments) in the axial-shear strain plane. Yield points at 0.001% plastic offset strain were determined from each stress-strain curves. The yield surface was obtained by fitting the experimental yield points to the Szczepinski anisotropic yield equation using the least squares method [3].

Region	Layer thickness [µm]	Hatch distance [mm]	Beam Comp [mm]	Focal point [mm]	Power [W]	Point distance [µm]	Exposure time [µs]	Scan speed [mm/s]	Energy density [J/mm^3]
Volume Fill Hatch	50	0.11	0.025	0	195	60	80	750	47.27
Scanning strategy	Meander								

Table 1. Process parameters applied during additive manufacturing

3. Results and conclusions

Figure 1(a) shows the material characteristics of Z-vertical build SS316L in the form of stress-plastic strain curves during pre-straining of the material. It can be observed that each curve initially exhibits an elastic region followed by plastic deformation. After unloading to zero stress, the material does not return to its original strain but retains permanent plastic deformation. Figure 1(b) depicts an evolution of the initial yield surface (as-printed) in the biaxial stress space that were obtained from experimental results at 0.001% plastic offset strain. The initial yield surface confirms the presence of initial anisotropy with a shift in the compression direction. The tensile plastic pre-strain leads to the softening of the material. A lowest degree of this effect was obtained after 0.5% plastic deformation.

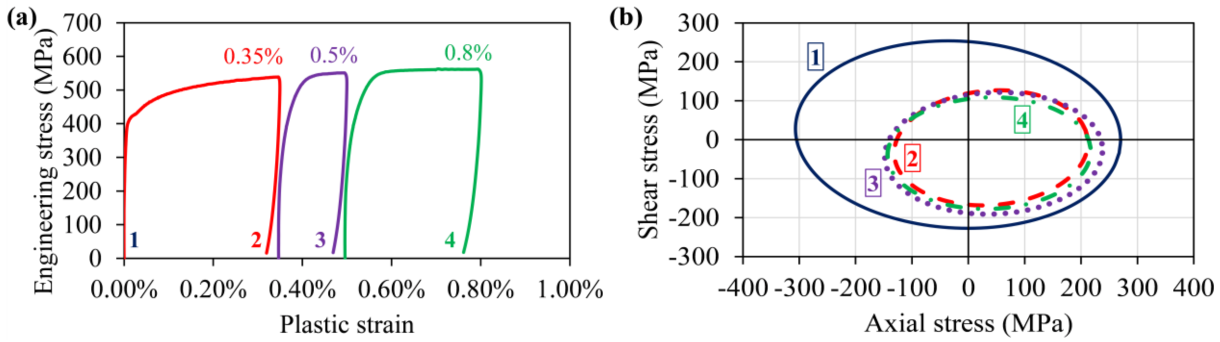

Fig. 1. Material response of SS316L (Z-vertical build) subjected to tensile plastic pre-strain equal to: 0.35% (2), 0.5% (3) and 0.8% (4) **(a)** and evolution of the initial yield surface (1) of Z-build SS316L due to such pre-deformation **(b)**.

4. Acknowledgements

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5. References

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