Determination of Yield Surfaces for Additively Manufactured 316L Stainless Steel

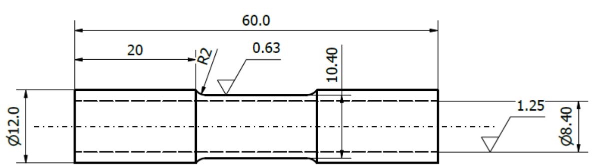
Z. L. Kowalewski, V. P. Dubey & M. Kopec
Department Experimental Mechanics
Institute of Fundamental Technological Research of the Polish Academy of Sciences
Poland

Highlights of Presentation

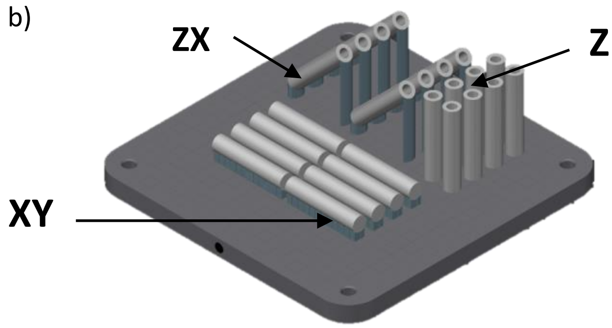
- Characterization of materials using only uniaxial testing methods provides only limited data. Mechanical testing under complex stress state due to combination of axial force and twisting moment better simulates real stress conditions.
- In describing an initial state of plastic deformation of a material, the yield surface concept plays essential role together with yield criterion.
- Experimental results captured provide a knowledge necessary for modification of some additive manufacturing processes.

Graphical Abstract

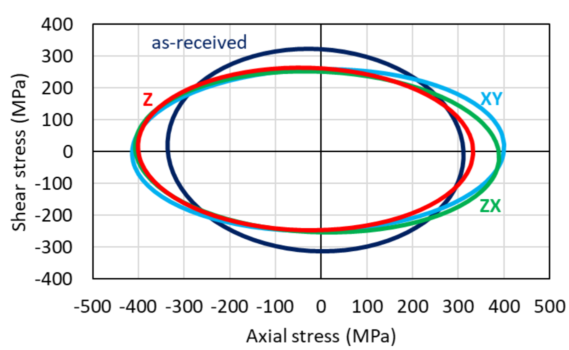
a)



b)



c)



Thin-walled tubular specimen for yield surface determination (a); printing orientation of specimens on the build plate (b); comparison of the yield surfaces for three printing orientations and the same material in the as-received state for 0.005% plastic offset strain (c)

Textual Abstract

The selection of the appropriate printing technology and parameters is crucial for ensuring a successful process during which crack-free components with extremely low porosity can be manufactured. Therefore, it is essential to apply optimized process parameters to achieve the required mechanical properties since they are strongly dependent on the AM process strategy applied. Uniaxial tensile tests conducted on SS316L manufactured using Selective Laser Melting (SLM), Laser Engineered Net Shaping (LENS), and some others have demonstrated superior properties in the horizontal and 45° orientations compared to the vertical orientation. It should be noted, that uniaxial testing provides only limited data on the anisotropy of AM SS316L, which is insufficient to fully understand all aspects of its behaviour, especially when different printing orientations are applied. The main aim of this paper is to experimentally determine an initial yield surface of AM SS316L for three printing orientations based on the yield point definition in form of the plastic offset strain equal to 0.005%.

The round bars and tubes of diameter and length equal to 13 mm and 70 mm, respectively, were additively manufactured by using the Renishaw AM 250 system. They were printed in three directions (Z – vertical, XY – horizontal, ZX – 45°) (Fig. b) using the Laser Powder Bed Fusion Melting (LPBF-M) method. After the AM process, the as-built specimens were subjected to stress relief using a 470°C soak for 6 hours whilst still attached to the build plate following standards. The bars were then wire cut from the build plate and subsequently machined to achieve the specimen geometry illustrated in Fig. a. Mechanical tests were performed on the MTS 858 servo-electrohydraulic biaxial testing machine. A detailed description of the methodology implemented for the precise strain measurement and control of tests was presented in (Dubey et al., 2023).

A single specimen approach and sequential probing technique under strain-controlled loading were successfully employed to determine an initial yield surface for each state of the material, involving 17 distinct stress paths. It was observed that the main dimensions of yield surfaces for LPBF-M specimens were increased along tensile and compressive directions, and shrunk significantly when torsion was applied. Such behaviour was associated with a certain form of material anisotropy representing different textures and crystal structures.

References

[1] Dubey VP, Kopec M, Łazińska M, Kowalewski ZL, 2023. Yield surface identification of CP-Ti and its evolution reflecting pre-deformation under complex loading. International Journal of Plasticity, 2023, 167, 103677.