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The role of microstructure on wear mechanisms and anisotropy of additively manufactured 316L stainless steel in dry sliding

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Additive manufacturing (AM) techniques can produce parts with tailored microstructure, however, little has been done to understand how this impacts the mechanisms of wear. Here we study the impact of initial grain arrangement and crystal orientation on the wear mechanisms of austenitic stainless steel (SS) in dry sliding contact. Specifically, the anisotropic sliding wear behavior of as-built, AM-ed 316L SS is compared against annealed, wire-drawn counterparts. We describe, in-detail, how the sliding wear mechanisms of delamination, abrasion, oxidation, and plastic deformation are attributed to the initial surface microstructure under different loading conditions using a combination of techniques.

Keywords: wear mechanisms, SLM, 3D printing, tribological properties, dry sliding wear

1. Introduction

Additive manufacturing (AM) techniques allows for producing parts with unconventional microstructures, which impact the mechanical properties of the produced parts [1]. However, little has been done to understand the role of microstructure of AM-ed components on the mechanisms of wear. This study aims to investigate the role of microstructure on the wear mechanisms of as-built AM-ed 316L Stainless Steel (SS) and compare that with annealed wire-drawn (conventional) counter parts in reciprocating dry sliding wear.

2. Methods

2.1. Sample Fabrication and preparation

Laser powder-bed-fusion (L-PBF) was used to fabricate 316L SS discs: T1, T2, T3 each with a different microstructure on the sliding surface. Wire-drawn 316L SS discs (specimen B) were used for comparison. All specimens were polished to $R_a < 800$ nm.

2.2. Microstructure Characterization

Electron-backscatter diffraction (EBSD) was used to characterize the sliding surfaces. The Taylor factor was calculated to account for the effect of crystal orientation on plastic deformation. A MATLAB code was written to visualize the high-angle grain boundaries (HAGBs) intersections with the Hertzian contact.

2.3. Wear test, measurement, and analysis

Samples were loaded on a linear reciprocating sliding tribometer HFRR for dry sliding wear tests. A wear profile was generated for 0.98, 1.96, 2.94, 3.92, 4.9 N loads. White-light interferometry was used to calculate the wear rate. Scanning electron microscopy (SEM) and energy-dispersive x-ray (EDS) were used to analyze the wear tracks.

2.4. Results

The Taylor and orientation maps, wear tracks, and HAGB intersections for each specimen type are shown in Figure 1.

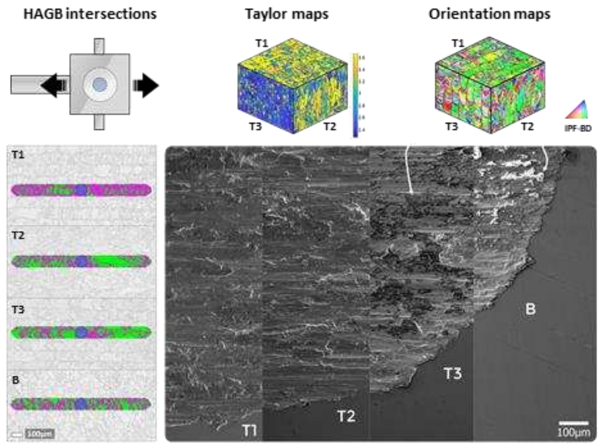

Figure 1: Dissimilar wear mechanisms were observed due to altered microstructures.

3. Discussion

The crystallography maps of the sliding surfaces showed that the normal load (N) was applied to a Goss (G) texture in T1, a rotated G (RT-G) texture in T2, a rotated cube (RT-C) texture in T3. On the other hand, N was applied to a mixture of ⟨111⟩ and ⟨001⟩ in the annealed components (B). The softest surface was B, followed by T3, then T2 and T1. This correlated with severe abrasive-oxidative wear in B showing oxide agglomerates and a noticeable abrasive-oxidative wear in T3 exhibiting the formation of oxide islands. On the other hand, T1 and T2, both depicted wear in the form of delamination and plastic deformation, owed to the G texture observed. This shows that wear mechanisms can be controlled based on initial microstructure of the surface, thanks to the flexibility of additive manufacturing processes.

4. References

[1] Wang, Y. Morris, et al. "Additively manufactured hierarchical stainless steels with high strength and ductility." Nature materials 17, 1, 2018, 63-71.