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Near-Net Dry Shaping of Titanium by Plasma-Carburized AISI420J2 Dies

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A pure titanium wire was employed as a raw work for upsetting and near-net forging to shape the biomedical parts and tools. A low temperature plasma carburizing was utilized to harden the bare AISI420J2 punches and to make them carbon-supersaturated. This carbon supersaturation was identified by the peak shift in XRD diagram as well as by the unbound carbon content in SEM-EDX. First, this carbon supersaturated AISI420J2 punch was utilized for upsetting of titanium wire to flat plate. Next, this forged plate was micro-/nano-textured by stamping to demonstrate that anti-galling near-net shaping could be done by this carburized punch.

Keywords: Forging, Near-net shaping, Anti-galling, Biomedical titanium, Carbon supersaturation

1. Introduction

A near-net shaping of titanium and titanium alloy into biomedical parts and tools, needs the anti-galling special tooling to be working in dry and cold [1]. The die materials must be properly selected to be free from adhesion of metallic titanium as well as titanium oxide debris particles. Although the AISI420J2 die material suffers from galling to titanium work, the plasma-carburized AISI420J2 (cs-AISI420J2) die was free from galling even in forging with high reduction of thickness [2, 3]. In the present paper, a pure titanium work with the diameter of 1.0 mm is forged by using this plasma cs-AISI420J2 punch down to a flat plate with the thickness of 0.3 mm. This plate is further shaped to have micro-/nano-textures by fine coining process. A role of in situ solid lubrication by isolated carbon from cs-AISI420J2 is investigated by these experiments.

2. Experimental Methods

A plasma carburizing system was employed to make carbon supersaturation into AISI420J2 die material at 673 K for 14.4 ks for upsetting and micro-/nano-texturing processes. Figure 1 depicts the outlook of cs-AISI420J2 punch with its SEM image and element mapping. Besides for the chromium oxide-carbide precipitates, the carbon solute uniformly supersaturates in the iron-chromium matrix of AISI420J2 die substrate. This punch is utilized in the forging and near-net shaping experiments.

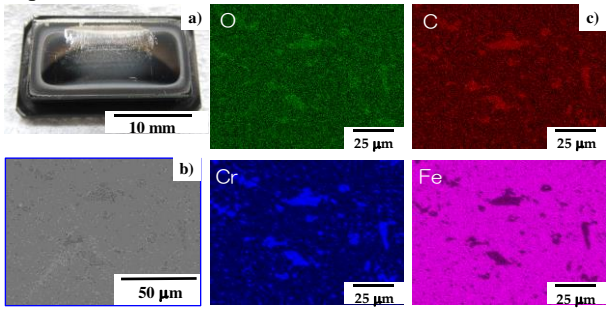

Figure 1: A cs-AISI420J2 punch with its SEM image and element mapping. a) Outlook of punch, b) SEM image of microstructure, and c) element mapping of O, C, Cr and Fe by EDX.

3. Results and Discussion

A pure titanium wire with the diameter of 1.0 mm was forged into a flat plate with the thickness of 0.3 mm in the reduction of thickness by 70%. Figure 2 depicts the variation of the forged wire in the plane view with increasing the reduction of thickness (r). When r > 30%, Wc approaches to Wo and less bulging deformation is observed in forging; e.g., Wc ~ Wo when r = 70%. This reveals that low friction state is sustained during this upsetting. This low friction as well as the forging behavior without galling stand on the in situ solid lubrication. As partially discussed in [2, 3], unbound free carbon isolates from the carbon supersaturated matrix of AISI420J2 punch and its agglomerates work as a solid lubricant. Different from low dimensional solid lubricants such as WS_2 and graphite, a contact interface of punch to work is only lubricated in solid by this free carbon agglomerates. Near-net shaping of forged flat plates is also accommodated by this in situ solid lubrication mechanism.

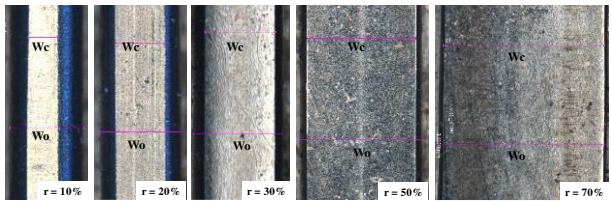

Figure 2: A galling-free upsetting of pure titanium wire with high reduction of thickness up to 70%. The width of contact interface (Wc) approaches the width of forged specimen (Wo) with increasing r.

4. References

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