In Situ Solid Lubrication in Cold Dry Forging of Titanium by Isolated Free Carbon from Carbon- Supersaturated Dies

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The anti-galling dry cold forging and forge-stamping processes of titanium and titanium alloys required for the in situ solid lubrication on the contact interface of dies to work. Two kinds of carbon-supersaturated dies were developed to make solid lubrication by free carbon isolated from die. These dies were utilized for dry cold forging continuously in 20 times up to the reduction of work thickness by 70% to form the contact interface on the die surfaces. SEM-EDX as well as Raman spectroscopy were employed to describe this in situ solid lubrication on the contact interface.

Keywords: carbon supersaturation, in situ lubrication, free carbon, cold dry forging, low friction

1. Introduction

The forging and forge-stamping of titanium and titanium alloys often suffers from severe galling onto die surfaces to stop the high reduction upsetting of raw materials [1]. Two die material selections are developed to suppress the titanium mass transfer to die materials [2, 3]. The forging experiment with high reduction ratio (r) of thickness by 70% is employed to describe their anti-galling behavior of pure titanium wire with the diameter of 1.0 mm. No significant deposition of titanium proves the anti-galling forging up to r = 70%. Less bulging deformation with increasing r, proves low friction in forging. Precise analyses are made on the contact interface of carbon supersaturated dies by using the SEM-EDX and the Raman spectroscopy. This demonstrates that the galling and friction on the contact interface is much reduced through the in situ solid-lubrication process by the tribofilm of free carbon solutes isolated from the carbon supersaturated die materials at the high forging stresses.

2. Methods

Two types of die material selections are proposed in this study; e.g., the carbon supersaturated, thick β-SiC coating to sintered SiC dies (cs-SiC) [2] and the plasma carburized AISI420J2 dies (cs-AISI420J2) [3]. CNC (Computer Numerical Control) stamper is utilized to describe the upsetting behavior of pure titanium wire up to the specified r. The relationship of applied power to stroke is monitored during forging. After continuously forging in twenty times by r = 70%, the contact interface is analyzed by SEM-EDX and Raman spectroscopy.

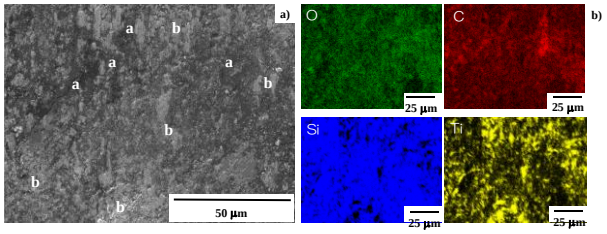

Figure 1: SEM-EDX analyses at the center on the contact interface of cs-SiC coating punch to pure titanium work. a) SEM image of carbon agglomerates and intermediate titanium oxide films, and b) element mapping.

3. Results and Discussion

Pure titanium wires were continuously forged in 20 times up to r = 70% by using the cs-SiC coating punch as well as the cs-AISI420J2 punch. A circular wire with the diameter of 1.0 mm was shaped to a rectangular one with the thickness of 0.3 mm. Little or no bulging deformation of wire reveals that the friction coefficient is less than 0.15 during this high reduction forging. Figure 1 shows the SEM-EDX analyses on the contact interface after continuous forging. The unbound free carbon agglomerates were formed as “a”-zone at the center of interface together with intermediate titanium oxide thin film as “b”-zone. These tribofilms are responsible for in situ solid lubrication and anti-galling forging. Figure 2 shows the SEM-EDX analysis on the contact interface of cs-AISI420J2 to pure titanium wire after continuously forging. The unbound carbon tribofilm isolated from cs-AISI420J2 also works as a solid lubricant.

4. References

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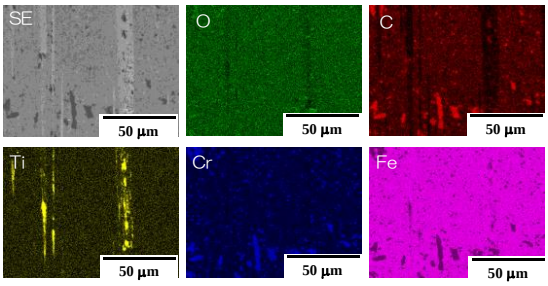

Figure 2. SEM-EDX analyses at the center on the contact interface of cs-AISI420J2 punch to titanium work. a) SEM image on carbon and titanium oxide layers, and b) element mapping.