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EFFECTS OF AGING AND SEVERE PLASTIC DEFORMATION ON TRIBOLOGICIAL BEHAVIOR OF AL 7075 ALLOY

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Abstract: *In this study, combine effect of equal channel angular pressing (ECAP) and subsequent aging treatments with different durations on Al 7075 – T651 alloy was investigated. Although ECAP process resulted in high dislocation density and created fine grains compared to Al 7075 over-aged condition, wear resistance of the alloy decreased. On the other hand, subsequent aging treatments, determined as under, peak and over-aged conditions, gradually raised wear resistance of the alloy. It can be concluded that, Al 7075 alloy's wear properties mainly depends on microstructure as well as mechanical properties.*

Keywords: *Al 7075 alloy, equal channel angular pressing (ECAP), aging, precipitates, friction and wear.*

1. INTRODUCTION

Due to their low density and high strength, aluminum alloys—particularly the Al 7xxx series—are increasingly used in aviation, marine, and automotive applications [1,2]. Al 7075 is a heat-treatable alloy that can be strengthened through aging processes [3]. Additionally, severe plastic deformation (SPD) techniques such as equal channel angular pressing (ECAP) can be applied to this alloy to enhance its mechanical properties by refining the microstructure to fine-grain (FG) or ultrafine-grain (UFG) levels [4]. Moreover, the presence of precipitates in the microstructure of age-hardenable alloys like Al 7075 contributes significantly to achieving the desired material properties. Both severe plastic deformation and aging processes influence the wear resistance of the alloy. Therefore, this study aims to investigate the combined effect of ECAP and aging treatments on the wear resistance of Al 7075 alloy.

2. METHOD

The wrought Al 7075–T651 alloy was first subjected to a solid solution treatment at 475 °C for 3 hours, followed by rapid water quenching. Subsequently, an over-aging treatment was applied at 290 °C for 13 hours. The over-aged samples were then processed using ECAP at 150 °C for four passes at route B_C. Following the SPD, a recrystallization treatment was conducted at 475 °C for 30 minutes, after which the samples were aged at 140 °C for varying durations. The hardness evolution of the ECAPed alloy was monitored throughout the aging process to identify under-aged, peak-aged, and over-aged conditions. Vickers microhardness measurements were performed using a 4.91 N load. Microstructural investigations for all conditions were carried out using Transmission Electron Microscopy (TEM) and Electron Backscatter Diffraction (EBSD). Friction and wear tests were conducted using a ball-on-disc type tribometer (UTS TRIBOLOG, www.uts-design.com) in reciprocating motion mode, following ASTM G133. The tests were performed under constant loads of 2, 4, and 10 N, at a frequency of 1 Hz, with an 8 mm stroke and a total sliding distance of 60 m, corresponding to 3750 cycles. A 6 mm diameter Al_2O_3 ball with a hardness of 2500 HV was used as the counter surface. The 3D surface topography of the wear tracks was analyzed using a non-contact optical profilometer, and the mass loss of the samples was measured using a high-precision balance with an accuracy of ±0.01 mg.

3. RESULTS AND DISCUSSION

Figure 1 illustrates the microstructural evolution of the Al 7075 alloy throughout the processing steps. Following solid solution treatment and subsequent over-aging at 290 °C for 13 hours, finely dispersed η phases and Fe-containing dispersoids were formed within the microstructure (Fig. 1a). Subsequent ECAP processing with four passes via route Bc introduced dense dislocation networks (Fig. 1b), significantly refining the grain size from 97.5 µm to 2.57 µm and increasing the hardness by approximately 60%, reaching 130 HV. Post-ECAP, three different aging durations were applied—2 h (under-aged), 8 h (peak-aged), and 204 h (over-aged)—to investigate their effects. In the under-aged condition, the microstructure consisted primarily of very fine Guinier–Preston (GP) zones, η′ ($MgZn_2$) precipitates, and Fe-containing dispersoids distributed throughout the aluminum matrix (Fig. 1c). In Al 7075 alloys, the typical precipitation sequence is: supersaturated solid solution (SSS) → GPB zones → η′ → η ($MgZn_2$) [5]. The under-aged treatment led to a 40% increase in hardness.

As aging progressed, the hardness peaked at 193 HV after 8 h, while the grain size slightly increased to 5.82 µm. This condition was identified as the peak-aged state. The corresponding microstructure (Fig. 1d) exhibited a high density of semi-coherent η′ precipitates, primarily located along grain boundaries, with a grain size of approximately 4.75 µm. Following the peak-aged condition, an extended aging treatment of 204 h was applied. This over-aging process transformed most of the semi-coherent η′ ($MgZn_2$) precipitates into incoherent η ($MgZn_2$) precipitates (Fig. 1e), resulting in coarsened precipitates and a slight grain growth to 5.06 µm.

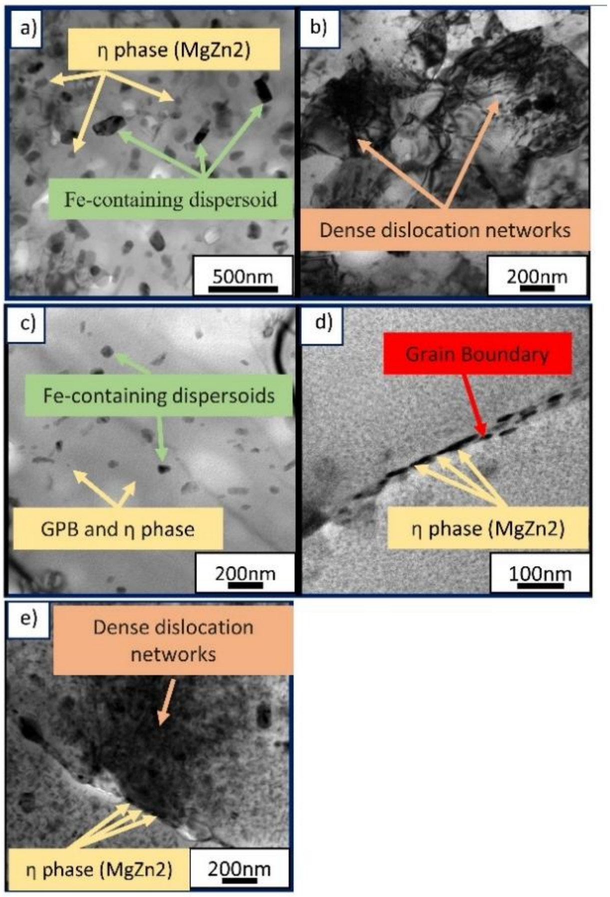

Figure 1. TEM images of five different condition of Al 7075 alloy

Figure 2 presents bar graphs illustrating the mass loss of Al 7075 alloy samples subjected to various processing steps under three different applied loads. It is evident that although the ECAP process increased the mass loss compared to the initial over-aged (OA) condition, subsequent aging treatments progressively improved the wear resistance of the alloy. This enhancement is likely attributed to the development of a sub-grained and more homogeneous microstructure as aging time increases [6–8].

Figure 3 shows the variations in the coefficient of friction (COF) for each condition. The results clearly indicate that the ECAP process initially increased the COF. However, the following aging treatments led to a reduction in COF values, which then remained relatively stable across the different aging durations.

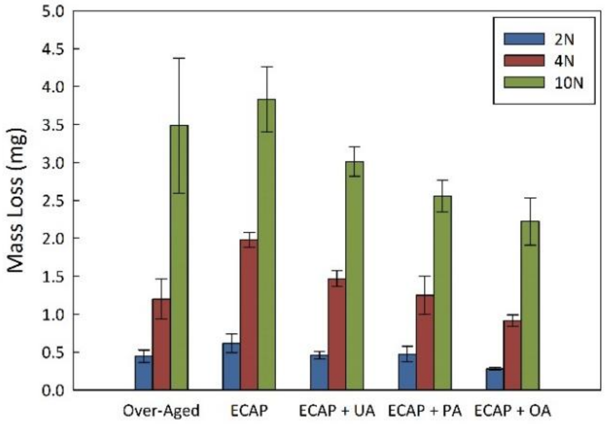

Figure 2. Mass loss bar graphs for each condition under three different loads

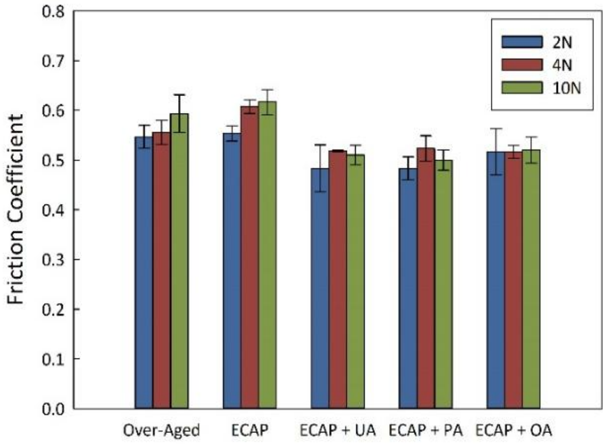

Figure 3. Coefficient of friction bar graphs for each condition under three different loads

Figure 4 represents 3D profilometer images for five different sample conditions. It was clearly observed that the ECAP process increased the wear depth significantly. However, with the progression of aging treatments, the wear scars became more uniform and the wear depth gradually decreased, indicating an improvement in surface resistance and wear performance.

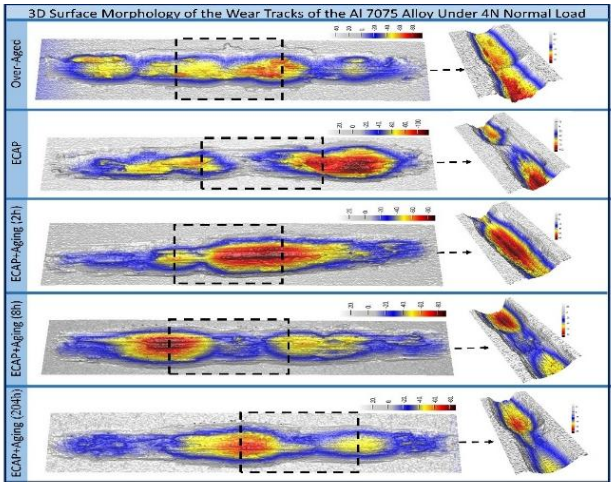

Figure 4. 3D surface morphology of the wear tracks of the Al 7075 alloy under 4N normal load

4. CONCLUSION

While ECAP processing significantly refines the microstructure of Al 7075 alloy, it initially reduces wear resistance due to the high dislocation density and surface roughness. However, subsequent aging treatments—particularly under-aged, peak-aged, and over-aged conditions—progressively enhance wear resistance of the alloy by promoting a more stable and homogeneous microstructure with favorable precipitate distributions. The findings demonstrate the critical role of post-ECAP aging in optimizing the tribological behavior of Al 7075 alloy for advanced engineering applications.

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