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AN INVESTIGATION ABOUT THE EFFECT OF LOAD ON DRY SLIDING WEAR PERFORMANCE OF AA7075-T6

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ABSTRACT

Aluminum alloys are taking the place of conventional steel and other alloys owing to their high mechanical and corrosion properties. The extensive application of AA7075-T6 in the aerospace, automotive and structure industries is due to its high strength-to-weight ratio, low corrosion potential and high machining properties and therefor requires detailed investigation. Frictional behavior of AA7075-T6 against Al_2O_3 *ball for low loads (3N, 5N and 7N) was investigated to characterize the worn surface in terms of wear rate and coefficient of friction (COF) using a pin-on-disc tribometer. Microstructural composition was depicted with optical microscope (OM). Wear rate and COF values were investigated accordance with different low test loads. A detailed tribological characterization was carried out using scanning electron microscope (SEM) and energy dispersive X-ray spectroscopy (EDX) and wear track profiles were observed. In the AA7075-T6 alloy present phases were determined using X-ray diffractometer (XRD) analysis. Morphological characterizations were accomplished by SEM and wear mechanisms were examined.*

INTRODUCTION

Aluminum alloys are replacing conventional steel and other alloys due to their high mechanical and corrosion properties [1], [2], [3]. Aluminum 7000 series alloys are used in various applications such as construction industries, aircraft, automotive and marine due to their light weight, better mechanical properties and good machining properties. Wear is an important problem in machine components caused by the interaction of two surfaces in contact with each other. Many studies have focused on determining the friction and wear properties of aluminum alloys [4]. 7075 aluminum alloys are widely applied in mold making, aerospace and mechanical equipment, especially for the fabrication of wear resistant aircraft structures and other structures with high strength and corrosion resistance [5]. Damage due to wear is a common problem in engineering components, devices and systems. In general, damage caused by wear can be reduced or even avoided by using stronger materials, which are usually very expensive. Therefore, AA7075 aluminum alloy is widely used in applications requiring high resistance to abrasion and forming stresses due to its light weight, good formability, high strength, and high thermal conductivity [6]. Friction is a specific wear process that occurs in the contact area between two components that come into contact under slight relative motion by vibration or some other force. This phenomenon can occur in many applications such as bearing shafts, automotive and aircraft parts, steam and gas turbines in contact with each other and can reduce the service life of components by half or more [7]. Researchers investigated the friction wear of AA7075 against AISI 52100 for 10N, 20N and 50N and found that the dominant wear mechanism consists of delamination, abrasive and oxidative wear. Plastic flow has occurred in the rotational friction zones [8]. Mao et al. examined the effect of sliding speed on the wear behavior for AA7075 petroleum casing and found that increasing the sliding speed changed the wear properties from abrasive and oxidative wear to adhesive delamination. Deep plows and craters were formed in abrasive wear and the wear mechanism turned out to be oxidative, including plastic deformation [9].

It is known that the formability of AA7075 is limited at room temperature [10]. Numerous studies have been conducted in the literature on various properties of the AA7075 alloy, including its wear behavior; however, researchers have generally investigated the wear performance of AA7075 at room temperature and relatively high loads (10N-106N) [11], [12], [13], [14]. Nowadays, the friction behavior and wear mechanisms of AA7075 specimens at low loads are still unclear. Therefore, in this study, the friction and wear behavior of AA7075-T6

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aluminum alloy against Al2O3 was investigated at low loads. This experimental work provides a detailed review of the tribological performance and wear mechanism of AA7075-T6 under 3N, 5N and 7N loads at room temperature.

MATERIALS AND METHOD

Firstly, the chemical composition of the AA7075-T6 alloy selected for the study was determined using EDX analysis as shown in Table 1. The results obtained from the field EDX analysis showed that the commercial AA7075-T6 alloy is consistent with its chemical composition and the elemental composition includes Al, Zn, Mg, Cu and Fe in descending order.

***Table 1** Chemical composition of alloy AA7075 in wt%*

Zn	Mg	Cu	Fe	Si	Mn	Ti	Cr	Al
5.22	2.42	1.32	0.49	0.27	0.09	0.03	0.20	Bal.

Afterwards, the samples were cut with a diameter of 40 mm and a thickness of 10mm and sanded using abrasive SiC sandpapers with 600, 1000 and 2000 mesh numbers, respectively. After sanding, the samples were polished with a 1 µm diamond particle solution on a 1 µm polishing broadcloth, and surfaces with an average surface roughness of Ra=0,0120 µm were obtained. The average hardness value of the commercially selected AA7075-T6 alloy sample measured as 158 HV.

Etching of the samples was carried out using Keller's reagent to provide a metallographic microstructure, and the optical microscope image of the sample is given in Fig. 1. Black and white regions were observed in a gray matrix in the microstructure. The EDX analysis showed that the white region has a composition rich in Aluminum (Al) and Iron (Fe) elements, and the black region is rich in Aluminum (Al), Silicon (S) and Magnesium (Mg). In this experimental work, as stated in the literature, it is seen that the Al-Mg-Zn-Cu alloy matrix may contain several intermetallic phases such as Mg_2Si, $MgZn_2$, $Al_2Mg_3Zn_3$, Al_2CuMg, Al_2Cu, Al_7Cu_2Fe and $Al_{13}Fe_4$.

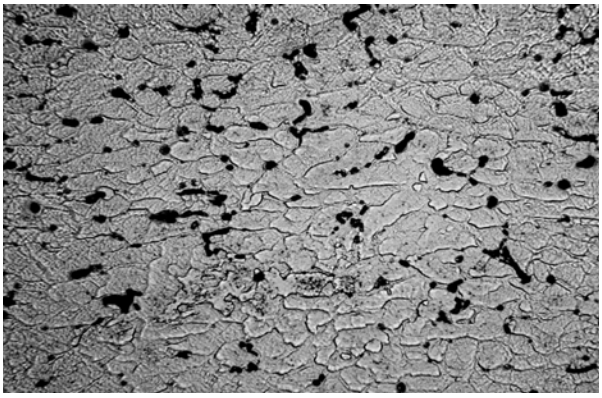

Fig. 1. Microstructure image of AA7075-T6 alloy

The phase composition on the material surface is one of the most important factors affecting the mechanical and tribological properties of the surface. In the AA7075-T6 alloy present phases were determined using X-ray diffractometer (XRD) analysis and results is given in Fig. 2. Microstructural observations in Fig.1, EDX analysis results in Table 1 and XRD analysis in Fig.2 showed that there are primary Al and secondary Al_2CuMg and Al_7Cu_2Fe phases in the matrix of AA7075-T6 alloy.

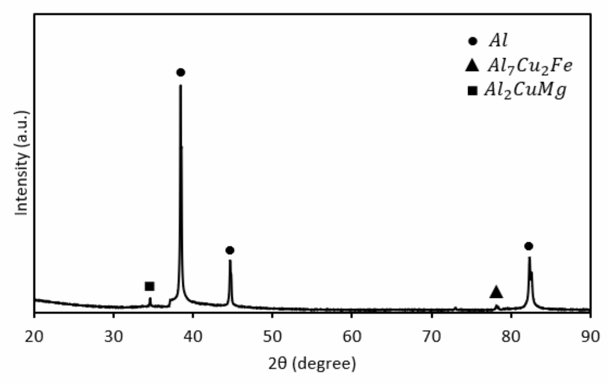

Fig. 2. XRD analysis of AA7075 samples

The frictional behavior of AA7075-T6 against a Al_2O_3 ball for three different low loads was investigated to characterize the worn surface in terms of wear rate and coefficient of friction (COF) using a pin-on-disc tribometer in accordance with ASTM G99-05 standards. The wear test parameters were specified as 25 min sliding time, 7 mm radius wear track and 100 mm/s sliding speed for a fixed temperature of 25°C. A Al_2O_3 ball with 6 mm diameter was used as a counterpart. Tests were carried out at 25°C and under 3N, 5N and 7N loads. Wear rate was obtained by formula 1 depending on wear track profile.

$$W = \frac{2\pi R\left[r^2 \sin^{-1}\left(\frac{d}{2r}\right) - \left(\frac{d}{4}\right)\left(4r^2 - d^2\right)^{0.5}\right]}{LP} \tag{1}$$

Fig. 3 shows the comparison of the friction coefficients of the samples after the wear tests for different loads. The average friction coefficients of the AA7075-T6 alloy samples, which were abraded under 3N, 5N and 7N loads, were determined as 0.3541, 0.3548 and 0.3453, respectively. For each load value, the friction coefficient is high at the beginning, and then it decreases slightly with the wear distance. It is thought that the surface roughness has an important effect on the friction coefficient being high at the beginning. The variation of the coefficient of friction for each load during the test period showed similar characteristics. It is thought that the close values of the friction coefficient are due to the relatively low applied loads.

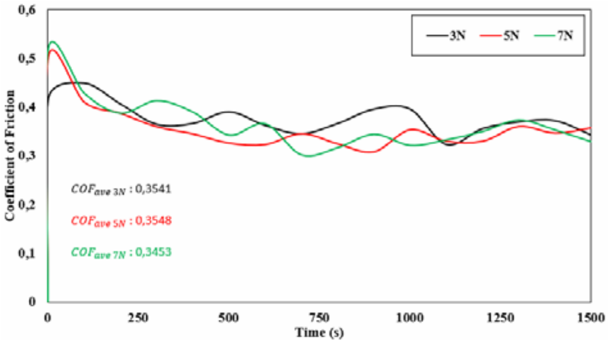

Fig. 3. COF at different loads

Fig. 4 shows the comparison of the wear rates of the samples after wear tests for different loads. The calculations showed that the volume loss of the worn samples under 3N, 5N and 7N loads was 3.89, 4.59 and 5.05, respectively. As can be seen from this, lower loads resulted in lower wear volumes. It has been determined that the wear rates decreased with increasing load in the wear rates calculated with formula 1. Increasing the load from 3N to 5N reduces the wear rate by approximately 29%; Increasing the load from 5N to 7N reduces the wear rate by approximately 21%. Kumar et al. in their study using 10N-50N loads on AA7075 hybrid alloy composites, they determined that the wear rate increased with the increase in load. However, in this study conducted with low loads, although the volume loss with the increase in load increases similarly to the literature, the wear rate decreases with the increase of the load from 3N to 7N. It is understood that low loads at constant sliding distance and at a constant temperature of 25°C will reduce the wear rate up to a certain value. However, if the applied load is 10N or more, it increases the volume loss excessively and has an increasing effect on the wear rate [14].

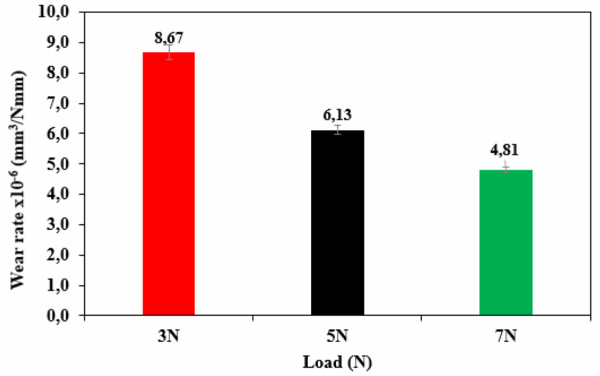

Fig. 4. Wear rate at different loads

Fig. 5, Fig. 6 and Fig. 7 shows the wear track characterizations obtained using SEM analysis of samples abraded at different loads.

In the SEM image of the wear track in Fig. 5, the wear direction was showed by white arrow and, the wear characterizations were indicated. Short and narrow groove formation has started due to abrasive wear along with the delamination caused by the accumulation of material on the ball.

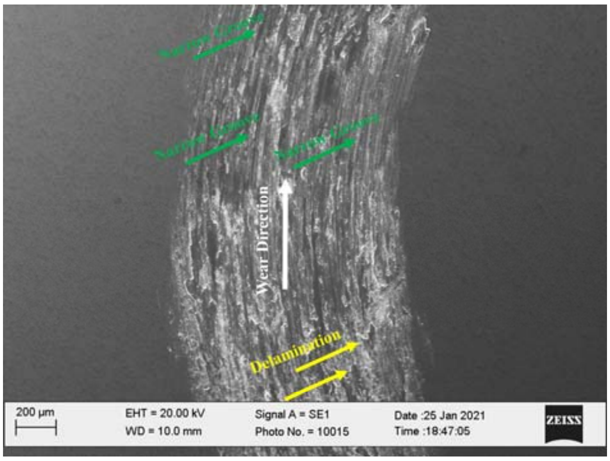

Fig. 5. Wear track under 3N

In the SEM image of the wear trace in Figure 6, the wear direction was showed by white arrow and, the wear characterizations were indicated. The dominant wear mechanism here is delamination resulting from plastic deformation. However, partial abrasive wear was also observed. With the effect of the load, pile up started to form on the edges of the wear track and the grooves became deeper.

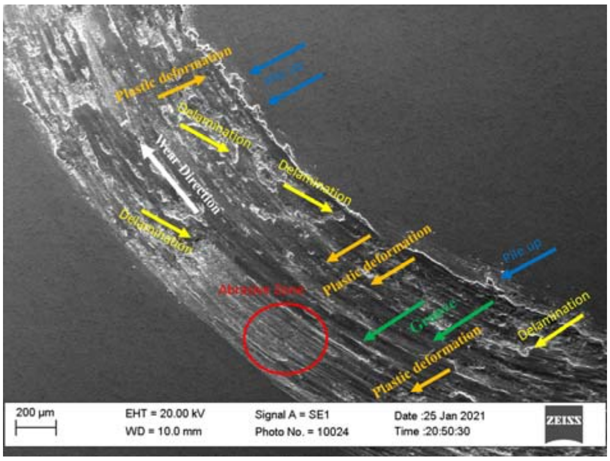

Fig. 6. Wear track under 5N

In the SEM image of the wear track in Figure 7, the wear direction was showed by white arrow and, the wear characterizations were indicated. At 7N, the rate of plastic deformation increased and the material piled up along the edge of the wear track. The size of the delamination and the number of deep grooves increased along the wear track. The dominant wear mechanism was determined as plastic deformation.

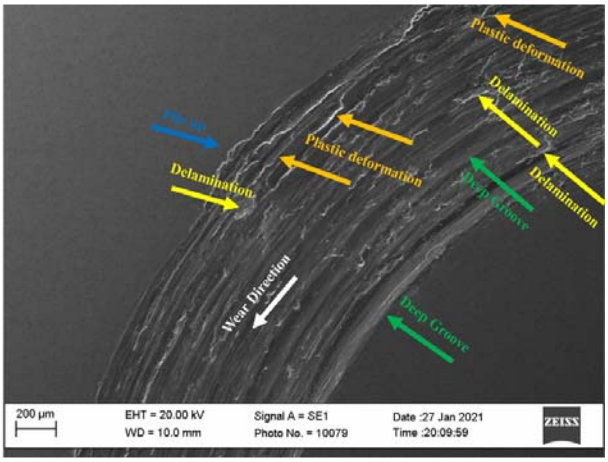

Fig. 7. Wear track under 7N

CONCLUSION

XRD model showed the existence of primary Al and secondary Al_2CuMg and Al_7Cu_2Fe phases.

While the average COF was approximately equal at 3N and 5N, it decreased slightly at 7N. The variation of the coefficient of friction for each load during the test period showed similar characteristics.

At 3N testing, short and narrow groove formation has started due to abrasive wear along with the delamination started.

At 5N testing, the dominant wear mechanism is delamination resulting from plastic deformation. However, partial abrasive wear was also observed. Depending on the applied load, pile up started to form on the edges of the wear track and the grooves became deeper.

The plastic deformation mechanism was effective at 7N and material piled up along the edge of the wear track. The size of the delamination and the number of deep grooves increased along the wear track.

The applied load increase resulted in an increase in volume loss. Contrary to high loads in literature, at low loads, the wear rate decreases with increasing load (from 3N to 7N).

It can be concluded that the wear rate applied at constant sliding distance and at 25°C temperature will decrease up to a certain value between 7N and 10N. In terms of determining this limit value of the wear rate, it is recommended to carry out further investigations at longer test times with small load increments such as 7.2N-7.4N...9.8N, provided that they are between 7N and 10N.

Longer test times can be considered as future scope of work for detailed detection of wear mechanisms and regime transitions occurring at low loads.

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