Effect of Fly Ash Content and Applied Load On Wear Behaviour of AA6063 Aluminium Alloy

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Abstract. The AA6063 alloy reinforced with 0, 2, 4 and 6 wt. % of fly ash (FA) particulate composites were produced by the compocasting technique. In this study, the effect of FA content and sliding speed on the wear behaviour of AA6063-FA composite was investigated. The wear was carried out by using pin on disc apparatus against rough steel counterface. These wear tests were conducted at applied load of 24.5, 49 and 73.5 N respectively with the constant sliding speed (150 rpm) and sliding time (10 minutes). In the results, it has been observed that upon addition of FA particles, the wear resistance of AA6063-FA composites was enhanced. The wear rate reduced with the increase in the content of FA particles. While the wear rate increased with increase in the applied load.

1. Introduction

The aluminium alloys are widely used in automobile industries as components of internal combustion engines such as cylinder heads, pistons and cylinder blocks due to light weight, high strength to weight ratio, and high thermal conductivity. The applications of aluminium alloys are limited because of poor wear resistance at room and elevated temperatures[1]. Aluminium metal matrix composites (AMMCs) are advanced materials, which aluminium metal combine as matrix material with the ceramic reinforcement such as SiC, Al2O3, B4C, TiB2 etc. to produce composite materials. AMMCs have a various application in different fields like airframes, driveshafts, pistons and submarine. For the past few decades, there has been a sharp demand for AMMCs due to their light weight and higher strength to weight ratio, wear resistance, higher thermal conductivity. These composites can be fabricated in different processes such as solid state (powder metallurgy) and liquid state processes (stir casting, compocasting, squeeze casting, in situ casting routes)[2].
The homogeneous mixing during the fabrication process between the metal matrix and different reinforcement shapes plays an important role determination of mechanical properties of these composites. Therefore, it’s one of the most significant mechanical properties that may be affected are the wear resistance. Generally, several factors are affected in the wear properties such as applied load, sliding distance, sliding velocity, friction temperature, and counterface hardness [3]. As well as the reinforcement contents, type, size and shape of materials are most factors that strongly influence in the wear properties [4, 5]. Various theories have been presented to give the influence of different parameters on wear mechanism of pure materials. But the wear mechanism in composite materials might be fundamentally different from the wear mechanism in pure metals. It is therefore difficult to determine the wear parameters required for these composite materials (AMMCs) unless these kind of parameters are closely studied by research.

Zhiqiang et al. [6] discovered that the wear weight loss of both the pure aluminum matrix and their silicon particle composites increased with increasing the applied load and sliding speed. The author’s highlighted to the lower frictional coefficient of the aluminum silicon composites and weight loss related with the unreinforced alloy samples more than 65N applied load value and vice versa. The transition of wear conditions of aluminum matrix occurred at the applied load value of 50 N. While their composite specimens demonstrated to enhance the wear resistance. However, under high loads (73.5 N), the protective layer of the reinforcement particles cannot stable longer remain under the compact, micro-cut action and ploughing and the abrasion grooves formed are more distinguished. This may be linked to the presence of large plastic strain in the deformed layers, which resulted in void nucleation, subsurface crack initiation and propagation. The surface material was removed from the wear surface and the cracks moved near to the surface. This led to the surface layers removal by delaminating wear [7, 8]. Rajmohan et al. [9] have highlighted that the wear rate increased with increasing value of applied load for the hybrid aluminum matrix composite specimens. The results of the ANOVA analysis indicated that load is the important parameter, which effects the wear loss of aluminum matrix composites followed by mass fraction of ceramic particles. It was also observed that the wear mechanism of the composites transformed from abrasion to delamination.

In this work, AMCs consisting of reinforced AA6063 alloy with FA particles produced by compocasting and the wear behavior of AA6063 alloy and AA6063-FA composites with 0-6 wt. % FA.

2. Material and methods

2.1. Matrix and Reinforcement Materials

In the present investigation, AA6063 alloy was selected as a matrix material. 6063 alloy is an aluminum based alloy often used in the automotive and aerospace industry. Chemical composition of AA6063 alloy consists of 0.008 wt. % Ti, 0.4 wt. %Mn, 0.01 wt. %Cr, 0.01 wt. % Zn, 0.01 wt. % Cu, 0.19 wt. % Fe, 0.51 wt. % Mg, 0.8 wt. % Si, 98.4 wt. % Al, was supplied by Kamco Aluminium Sdn Bhd, Malaysia. The FA particles was selected as a reinforcement material. The chemical composition of FA powder consists of 0.01 wt. %CuO, 0.34 wt. %Na2O, 0.38 wt. %MgO, 0.63 wt. %CaO, 0.09 wt. % K2O, 1.14 wt. % TiO2, 2.78 wt. % Fe2O3, 19.09 wt. % Al2O3, and 95.98 wt. % SiO2. The particle size is 44µm, it was obtained from Tanjung Bin Power plant in pontian, Johor, Malaysia.

2.2. Manufacturing the Composite Material

The proper selected parameters of manufacturing process is important to produce the composite by compocasting technique such as molten temperature, stirrer speed, preheating temperature of reinforcement etc. preparation of the composite was carried out according to the following procedure:

AA6063 alloy was heated up to molten state in graphite crucible by induction furnace. The temperature of the melt was about 800°C, and start stirring process by stainless steel stirrer (Figure.1). Then reduce the temperature to 600°C to get semisolid state of the molten AA6063 alloy aluminium and add the preheated FA particles (900°C for 2 hours). Then increase the temperature with stirred the
mixture 300 rpm. After completing the addition of the FA powder into the melt, the AA6063-FA composite was poured into the preheated mould about 250°C and allowed to cool in atmospheric temperature. The cast was then detached from the mould and the samples of wear test machined with heat treatment with different weight fractions of FA reinforcement (0-6%) in step 2%.

2.3. **Wear Test**

The dry sliding wear behaviour test of AA6063-FA composites was carried out under ambient condition using a Pin on Disc apparatus (DUCOM’s wear friction Monitor, Model-TR-20LE, Bangalore, India). Ducom Rotary Tribometer complies with ASTM G99-05 standard [10]. Figure 2 demonstrates the wear test conducted in the Tribology Laboratory at Universiti Teknologi Malaysia (UTM), under varying applied load (24.5, 49, and 73.5N) and at a fixed sliding speed of 150 rpm up to sliding time 10 min against hardened steel disc EN32 with hardness 60HRC. Wear test specimens were cut into rectangular bares to the dimensions of 8mm×8mm×24mm as shown in Figure 2 [11, 12]. The test surface was adequately polished using different grades of silicon carbide papers to ensure the proper contact with steel disc. During sliding test, the load is applied on the specimen through cantilever mechanism and the specimens brought in intimate contact with the rotating disc at a track radius of 80 mm (Figure 2), the specimens were cleaned with acetone. The wear rate was calculated from the volumetric loss per unit sliding distance. An investigation graph shows the height loss or wear in µm against slippery time in sec (which is proportional to sliding distance) taken from wear testing machine is shown in Figure 3.
3. Results and discussion

The wear test results of the AA6063 alloy and AA6063-FA composites under dry sliding conditions are shown in figure 4. The overall slippery time of 10 minutes at sliding speed 150 rpm under varying weight fraction of FA (0-6%) in step 2% were studied. The wear rate of these test was obtained from the weight loss is plotted against applied load as shown in figure 4 for different FA content. The incorporation of FA particles was beneficial to the enhancement of wear resistance. The increased wear resistance was attributed to the higher hardness of the AA6063-FA composite according to increased FA content [13]. The results of added FA to composite were improved hardness offer resistance to the cutting action of the counterface asperities. The thermal mismatch between the AA6063 alloy and the FA particles created dislocations during solidification, those strain fields strengthen the subsurface. The homogenous distribution of FA particles led to Orowan strengthening [14].
Figure 4. Wear rate of 6-FA composites at 150 rpm as a function of wt. % FA with variant load: (a) 24.5N, (b) 49N, and (c) 73.5N.

The wear weight loss of the AA6063-FA composite increases with increasing in the applied load. From the figure 5, it is clear that wear loss of unreinforced AA6063 alloy increases higher than AA6063-FA composite. An increased applied load on the sliding specimens increased the pressure on the sliding specimen. These results are in agreement with the well-known Archard’s wear expression equation 1 [15, 16] Archard’s law steady state wear was proportional to contact stress or pressure and sliding distance for these metallic composites.

\[ W = KP_n/H \]  

Where \( H \) is the indentation hardness of the softer surface, \( K \) is the wear coefficient of Archard which is dimensionless (always less than unity) and \( P_n \) is the normal pressure applied between the surface.
4. Conclusion
In the present work, AA6063-FA composites were prepared by the compocasting technique. The effect of reinforced FA content and applied load on the wear behaviour of AA6063 alloy were investigated. The reinforcement of AA6063 alloy with FA particles has a significant effect on the wear behavior. The wear rate decreases with increasing the weight content of FA reinforcements. The results of this investigation are indicated about increasing the wear resistance when increases the FA content at constant sliding speed. As well as the wear rate decreases with increase in applied load.

Acknowledgements
The authors would like to thanks the Ministry of Education Malaysia (MOE), Aerospace Department in Faculty of Engineering at University Putra Malaysia (UPM) and Mechanical Engineering Faculty, UTM-Centre for Low Carbon Transport, Institute for Vehicle Systems and engineering at Technology University Malaysia (UTM) for providing the research facilities. This research work has been supported by the Ministry of Education Malaysia (MOE) for the FRGS Grant (R.J130000.7824.4F723), UPM Research Grant (9487900) and UTM research grant Q.J130000.2524.17H83.

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