Wear Characterisation of AL6061 based Hybrid Composites

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Abstract

This research work describes the abrasive wear rate of as-cast AL (6061) alloy reinforced coated albite and graphite particulates .The present investigation is on the wear behaviour of AL6061/Albite/Graphite reinforced hybrid composites. Dry sliding wear behaviour of AL6061 based hybrid composites has been investigated using a pin-on-disc wear-testing machine. The hybrid composite showed appreciable improvement in wear rate due to better interface bonding. The composites containing both Albite and Graphite exhibited a transition from mild to severe wear with application increasing normal applied loads. The transition from mild wear to severe wear was influenced by the applied load, sliding distance, hardness and strength of the hybrid material.

Key words: Hybrid composites, Albite, Graphite, wear, AL6061

1. Introduction

Aluminum is the most widely used matrix material, in the investigations involving metal matrix composites (MMCs). This is mainly because of the unique combination of its low density, high strength, good mechanical properties, good corrosion resistance, low electrical resistance, and good machinability properties [1–2]. The relatively poor wear resistance of aluminum alloys has, however, limited their use in certain tribological applications. In recent years, both fiber and particulate reinforced aluminum alloy composites fabricated have shown significant improvement in tribological properties, including sliding wear, abrasive wear, friction and seizure resistance [3]. It has also been demonstrated, that the wear-rate data of MMCs can be neither correlated with their bulk mechanical properties, nor rationalized on the basis of rules of mixtures. Only limited number of fundamental studies have been reported on the sliding wear behavior of composites [4–7]. In the present study, an in-depth investigation was carried out on the dry sliding wear behaviour of a cast AL6061 alloy, reinforced with garnet particulate. The high temperatures reached during sliding affect the physical and chemical properties of the sliding surfaces and influence their friction and wear behavior [8].

This paper examines the effect of graphite particulate on the abrasive wear resistance of albite particulate and graphite reinforced AL(6061) based hybrid composites, which are candidate materials for aerospace and automotive components which require fabrication processing and relate changes in the wear properties to the microstructural changes in the Al alloy matrices. The weight fraction of 4% albite particulates kept constant and varying graphite content from 1 to 4 % and were used for making MMCs. Keeping this in this study, dry sliding wear tests were conducted on ascast hybrid composites using pin on disc wear testing machine at a sliding velocity of 6.23m/sec at varying applied loads of 30N,50N and 70N load and maintain a constant sliding distance of 3000m. In addition to this a systematic evaluation of the wear rate characteristics and a systematic worn out surface examination was carried out using scanning electron microscope.

The incorporation of Albite and Graphite particulate reinforcements in an AL6061 alloy increases, its load bearing capacity and hence the load and sliding speed range within which dry sliding wear is mild This has been investigated in detail which opens new avenues AL-based metal matrix composites in applications where sliding resistance is of concern. The aim of this paper is to examine on the wear resistance of Albite particulates and Graphite particulates reinforced AL(6061) based hybrid composite , which are candidate materials for aerospace and automotive components. The weight fraction of 4% Albite and varying graphite content 1-4 wt% for making metal matrix hybrid composites (MMHCs).

2. Experimental Procedures

2.1 Materials

Table 1: Chemical composition of AL6061 by weight percentage

Aluminium 6061 alloy		
Mg	Si	Fe
0.92	0.76	0.28
Cu	Ti	Cr
0.22	0.10	0.07
Zn	Mn	Be
0.06	0.04	0.003
V	Al	
0.01	Bal	

Table 2: Chemical composition of AL6061 by weight percentage

Albite	
Silica(6SiO_2)	Alumina
68.7	19.5
Soda	
11.8	

The matrix material used for the MMCs in this study is AL6061 alloy. This alloy is best suited for mass production of lightweight metal castings. Table 1 show's the chemical composition of AL 6061 and Table 2 the chemical composition of the albite. The albite and graphite 50-100microns were reinforced in the matrix material.

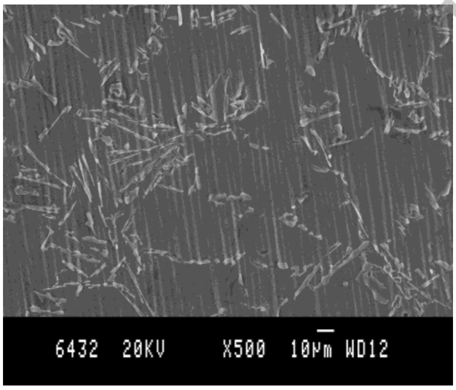

Figure 1: SEM of 4% of Albite and 4% Graphite Reinforced AL6061 based Hybrid Composite

Liquid metallurgy technique was used to fabricate the composite materials in which the reinforcing materials were introduced into the molten metal pool through a vortex created in the melt by the use of an alumina coated stainless steel stirrer. The coating of an alumina to the blades of the stirrer is essential to prevent the migration of ferrous ions from the stirrer into the molten metal. The stirrer was rotated at 500 rpm and the depth of immersion of the stirrer was maintained about two-thirds the depth of the molten metal. Reinforcing materials preheated at 300°C were added one after the other into the vortex of the liquid melt which was degassed using pure nitrogen for about 3 min - 4 min prior to the addition of the reinforcements. The resulting mixture was tilt poured into the preheated permanent metallic molds.

2.2 Wear Tests

Wear tests were carried out using a pin -on -disc machine. The tests were carried out by rubbing a hybrid composite specimen against a rotating disc of steel (200mm diameter and 58 ± 0.5 HRC) under dry conditions. Before testing, the surfaces of both the pin and disc wear samples were polished with 400, 600, 800 and 1000 grit emery papers. The surface roughness's of specimens were about 0.3 µm .

The test environment was kept at a room temperature· and a relative humidity of 30% (measured using dry and wet bulb thermometer). Sliding velocity of 6.23 m/sec for a sliding distance of 3 Km and a loads of 30 N-70N. Before and after testing the weight of the pin was measured to an accuracy 1O^{-4} gms using a digital balance to determine mass loss and each hybrid composites were tested four times. Lastly, wear surface-were studied with SEM to determine the wear mechanism undergone by the material.

3. Results and Discussions

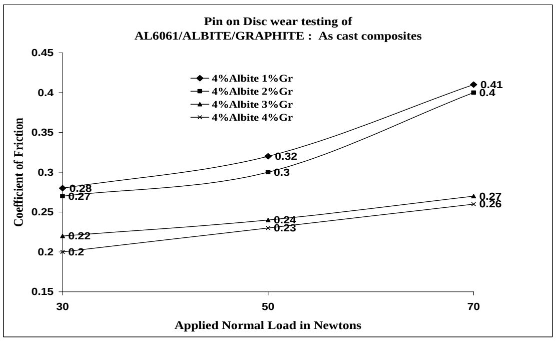

Figure 2 Coefficient of friction vs. Applied Load

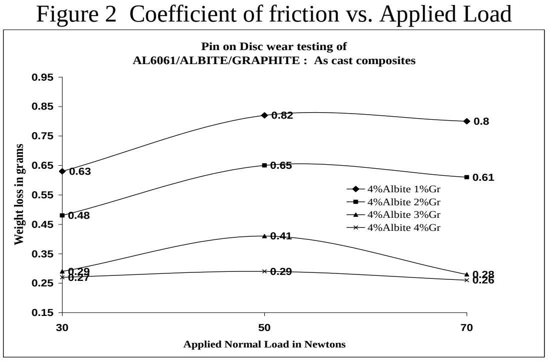

Figure 3 Weight loss vs. Applied Load

3.1 Effect of load on the wear rate at low loads (30N)

The wear loss and coefficient of friction of as cast composites under dry sliding condition for a constant sliding distance of 3000mts and sliding velocity of 6.23m/s are shown Figure 2 & 3, shows a steady state mean values of coefficient of friction as a function of applied load for as cast AL6061/Albite/Graphite composite subjected to dry sliding wear. Superior steady state wear resistance was observed by the reinforced composites, as well as unreinforced matrix alloy at lower loads.

The mild wear occurs at lower loads where the contact resistance is high. The wear debris is fine and it consists mainly of aluminum and iron oxides. The rubbed surface seems to be polished. At lower loads, the particles act as load bearing and abrasive elements, between the composite and steel disc. The worn surface of the Aluminum-Albite - Graphite composite exhibits formation of iron-rich layers, at lower loads. The worn surface figure shows white patches (iron oxide) on the contact surface of an aluminium/albite/graphite composite specimen.

3.2 At Medium Loads (50N)

At medium loads, the specimen wears at a uniform rate. The composite exhibits smaller plastic deformation and damages due to cavitation de-cohesion taking place along the sliding direction of the surface. Formation of the iron oxide is lesser at medium loads than that at lower loads. Presence of aluminum oxide has also been detected at the morphological surface. Figure 4 , shows the features of worn surface of 4% Albite 4% Graphite reinforced composites. The worn surface does not show the presence of exposed particulate at medium loads due to the rise in temperature, the matrix becomes soft, the particulates are pushed in to the matrix

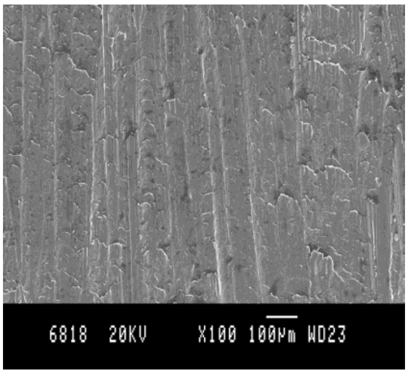

Figure 4 Worn surface SEM of AL6061/4%Albite / 4%Graphite Hybrid Metal Matrix Composite

3.3 At higher loads (70N)

The oxide film prevents metal to metal contacts. The hard brittle oxide formed on aluminum provides protection against wear. It is clearly evident from the graph, that there exists a transitional load at which there is a sudden increase in wear rate of both reinforced as well as the unreinforced material. In 4% Albite 4% Graphite reinforced as cast composites, the Graphite particulates serves to suppress the transition to a severe wear rate. In the severe wear region at higher loads, the contact resistance is low. Wear debris includes coarse metallic particles of the surfaces and ceramic particles, which act as abrasive particles between the specimen and disc.

4. Conclusions

The introduction of reinforcing particulates namely Albite and Graphite particulates in AL6061 matrix reduces the wear rate. The wear rate of the AL-based hybrid composites do not depend on type of reinforcement, but wear rate of the hybrid composites decreases with increasing the weight percentage of reinforcing materials. The role of graphite as solid lubricant has proved to be effective in enhancing the wear resistance of base alloy. Weight loss is increased linearly with increasing sliding velocities Graphite not only reduces the hardness of the composite but also provides the lubrication necessary to curtail the wear of the hybrid composite. Studies have been carried out to determine the influence of albite and graphite reinforcements on the wear resistance of the hybrid composite material. It has been determined that the erosive performance of the steel disc generates a slighter oxidation on the surface of the material tested at medium sliding velocities. The presence of hard ceramic albite particulates in base alloy has provided necessary strength but with addition of softer graphite particulate has infused some increase in ductility with marginal compromise reduction in strength and hardness. But significantly enhanced the wear resistance of the synthesized hybrid composite. Thus, for wear resistance applications, metal matrix hybrid composites based on AL6061 appears to be an attractive alternative composite material for high end applications.

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