International Journal of Engineering Applied Sciences and Technology, 2016
Vol. 1, Issue 12, ISSN No. 2455-2143, Pages 81-84
Published Online October-November 2016 in IJEAST (http://www.ijeast.com)

EXPERIMENTAL INVESTIGATIONS ON WEAR CHARACTERISTICS OF HEAT TREATED AL6061 HYBRID COMPOSITES

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Abstract- **A Composite material is composed of two or more constituents that differ in shape and chemical composition and which are insoluble in each other. Modern composite materials are optimized to obtain a particular properties for a given applications. Metal matrix composite materials have been found in many applications in different fields. In this research paper, stir casting technique was used to fabricate the Al6061 composite specimens reinforced with tungsten carbide and graphite particles. Graphite particles are added as 2% with 5%, 10%, 15%, 20% of tungsten carbide particles in Al6061 metallic matrix. The composite specimens are kept in muffle furnace in temperature of 440°K for duration of two hours followed by water quenching. Wear tests were carried out using pin-on-disc apparatus with data acquisition system. The result shows that increasing reinforcement of tungsten carbide (WC) leads to increases the wear resistance and reduces the coefficient of friction of the composites. Heat treatment process further increases the wear resistances of both reinforced composite and unreinforced alloy.**

***Keywords*: Hybrid composites, Aluminium composites, Heat treatment, Wear testing**

I. INTRODUCTION

Metal Matrix Composites (MMCs) have a lot of advantages over conventional materials which includes higher specific modulus, better properties at elevated temperatures, better wear resistance, higher specific strength and lower coefficients of thermal expansion [1]. Because of these properties MMCs are considered for a extensive range of applications like aerospace industry for airframe and spacecraft components, automotive, electronic and recreation industries [2]. In general MMCs consists of a minimum two components namely matrix and reinforcement. Matrix is a metal, but pure metal is rarely used: it is generally an alloy. The reinforcements can be continuous fibres, discontinuous fibres, whiskers, wires and particulate. Expect wires, which are metals, reinforcements are generally ceramics. These ceramics are oxides, carbides and nitrides [3,4].They are excellent combinations of specific strength and stiffness at both ambient temperature and elevated temperature. Commonly used metal matrices are based on aluminium and titanium. Both of these metals have low specific gravities and available in a variety of alloy forms. Although magnesium is even lighter, its great affinity for oxygen promotes atmospheric corrosion and makes it less suitable for various applications. Beryllium is the lightest of all structural metals and has a tensile modulus higher than that of steel. However, it suffers fromextreme brittleness, which is the reason for its exclusion as a potential matrix material. Nickel- and cobalt-based super alloys have also been used as matrices, but the alloying elements in these materials tend to accentuate the oxidation of fibres at elevated temperatures [5-7]. Aluminium and its alloys have the most attention as matrix material for MMCs and the most common reinforcement is SiC[8]. Various processing techniques have evolved tooptimize the microstructure and mechanical properties of MMCs. The process of stir casting generally involvesthe admixture of ceramic particulate reinforcement with a molten metal matrix. The particulates are distributed and suspended in the molten metal via high energy mixing or another appropriate process. The suspended slurry is then cast as a foundry ingot, extrusion billet or rolling bloom [9]. Wear resistance is an important function in the balance of properties provided by MMCs. The addition of hard reinforcements intrinsically improves the wear resistance of the host metal. Further, additions such as graphite can also provide intrinsic lubricity. The effect of heat treatment has been found to be the very important parameter in determining the friction coefficient and wear rate for some kinds of discontinuously reinforced composites [10-13]. In view of these literatures, this study was undertaken to determine the effect of heat-treatment on the wear properties of Al6061 composites reinforced with tungsten carbide and graphite particles.

II. EXPERIMENTAL DETAILS

A. Materials-

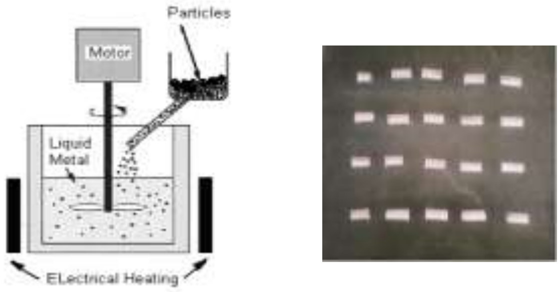
The matrix Al6061 used in this work is a commercial heat treatable aluminium alloy and extensively used in aerospace industries. The nominal chemical composition of the matrix is given in Table.1. The reinforcement particles used for this investigation are tungsten carbide and graphite particles with an average size of 75 microns.

Table 1. Chemical composition of Al 6061 alloy

Element	Cr	Cu	Fe	Mg	Mn	Si	Ti	Zn	Al
wt. %	0.003	0.24	0.16	0.8	0.4	0.63	0.01	0.007	Bala

B. Specimen Fabrication-

Composite specimens consist of Al6061 alloy, 2% graphite particles with 5%, 10%, 15%, 20% of tungsten carbide particles are fabricated using liquid metallurgy route shown in (Fig.1a). This method is most economical to fabricate composites with discontinuous fibers or particulates [14]. Al6061alloy was properly cleaned prior to melting to eliminate any impurities on its surface. The reinforcement particles are preheated to remove its moisture content. The matrix is placed inside a graphite crucible. Very small amount of magnesium i.e. less than 0.5% of total weight of mixture was added into the crucible which acted as wetting agent to bind molten metal and reinforcement powder. It was then superheated above its melting temperature and then temperature is lowered gradually below the liquidus temperature to keep in semisolid state. At this temperature, the preheated tungsten carbide and graphite particles were introduced into the slurry and mixed. The composite slurry temperature was increased to fully liquid state and automatic stirring was continued to about ten minutes at an average stirring speed of 300-350 rpm. After mixing the reinforced material, the molten material is poured into the pattern that already prepared for our required shape and size and then machined to a size of 10mm diameter and 25mm length (Fig.1b).



(a) (b)

Fig. 1. (a) Stir Casting Setup (b) Composite specimens

C. Heat Treatment

Heat treatment of Al6061 composite specimens further increases the strength of composites [15]. The fabricated composite specimens are kept in a muffle furnace (Fig.3) at a temperature of 440°K for duration of two hours. Followed by this water quenching is done for all specimens. Artificial aging was carried out at 448K for duration of 6hours.

Fig. 2 Heat treatment of composites

D. Wear testing:

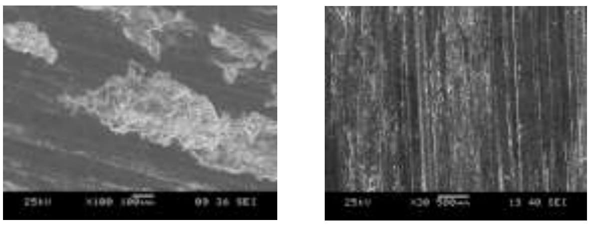
Wear tests were carried out using pin-on-disc apparatus with data acquisition system (Fig.3). The experiments were conducted by rubbing a hybrid composite specimen against a rotating disc. The tests were conducted at a room temperature with a relative humidity of 30%. The mass loss of the pin in microns was recorded during each wear test using a transducer. The linear downward motion of the pin is thus a measure of the wear loss of the pin material that is being recorded by the provided in the wear testing apparatus. Each experiment was carried out for three times and the best test result obtained was taken for wear analysis.

Fig.3 Pin on Disc Apparatus

III. RESULTS AND DISCUSSIONS

A. Microstructure Study-

Micrographs of the wear surface of the un heat treated Al 6061 hybrid composite specimens is shown in Fig.4a. After wear of the composite specimen (Fig.4b), a non-uniform wear consisting of grooves, micro cutting and scratch marks have been formed by the reinforcing materials were observed. This shows that the wear of the composite is due to abrasion wear. Delamination is also observed on the wear surface of the composite which induces sub surface cracks that gradually grow and eventually shear to the surface, forming long thin wear sheets.



a b

Fig.4 SEM image of a) unheat treated composite b) Heat treated composite

B. Wear study-

Effect of sliding distance on weight loss:

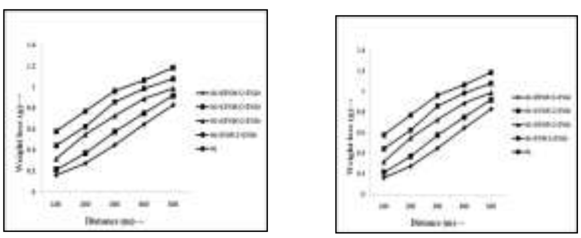


Fig.5a) Effect of sliding distance on weight loss with WC and Graphite b) Effect of sliding distance on weight loss with WC only

Effect of applied load on weight loss:

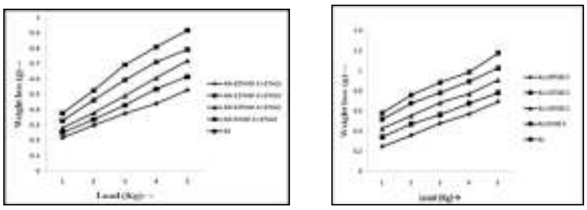


Fig. 6a) Effect of applied load on weight loss with WC and Graphite b) Effect of applied load on weight loss with WC only

Fig.5 shows the effect of sliding distance on the weight loss of Al6061 composite reinforced with tungsten carbide and graphite particulates. Weight loss is plotted against the sliding distance. It is evident that, increase in percentage of tungsten carbide is directly proportional to increase in wear resistance. The addition of graphite particulates in the composites further reduces the wear rate. The effect of sliding distance on the weight loss of composites reinforced with tungsten carbide only is shown in Fig.8. From this figure, it can be noted that the wear rate of the composites are almost similar to the specimens reinforced with graphite particles also. This can be due to the poor wettability of the graphite particles with the aluminium matrix material. The similar observation was obtained by the previous researcher [16]. The effect of applied load on the composite weight loss of Al6061 reinforced with WC and graphite particulates is shown in Fig.6a. It can be noted that the weight loss of composites reduces gradually for increasing in the weight percentage of tungsten carbide particles. In Fig.6b, for calculating the weight loss of the composite, the graphite particles are not considered. Due to the presence of tungsten carbide particles only the weight loss of the composite reduces over a considerable amount.

IV. CONCLUSION

The major conclusions drawn from the present study on the wear characteristics of heat treated hybrid metal matrix composites are:

1. The composite specimens were fabricated using stir casting method.
2. Scanning Electron Microscopic examinations of the wear surfaces of heat treated composites shows abrasion, delamination and adhesion.

3. Increase in the reinforcement of tungsten carbide (WC) leads to increases the wear resistance of the composites.
4. Addition of 2% graphite particles leads to lubrication which further increases the wear resistance of hybrid composites.
5. Heat treatment process improves the wear resistance of composite specimens.

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