PROCESSING AND WEAR BEHAVIOR OF Al₂O₃ PARTICULATES REINFORCED AL-4.5 % Cu ALLOY COMPOSITES

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Abstract- High strength Al-4.5 wt. % of Cu alloy matrix composites with 2 and 4 wt. % of Al₂O₃ particulates reinforced composites were synthesized by stir casting method. Microstructural analyses of Al-Cu alloy composites were performed by using optical microscopy. Microstructural characterization of the developed Al-Cu-Al₂O₃ composites revealed uniform distribution of micro size Al₂O₃ particulates in the base matrix. The wear resistance of metal matrix composites was studied by performing dry sliding wear test using a pin on disc apparatus. The experiments were conducted at a constant sliding velocity of 1.413m/sec and sliding distance of 2000m over a varying load of 10N, 20N, 30N and 40N. Similarly experiments were conducted at a constant load of 30N and sliding distance of 2000m over a varying sliding speed of 0.942, 1.413 and 1.884 m/sec. The results showed that the wear resistance of Al-Cu-2%Al₂O₃ and 4% Al₂O₃ composites were better than the unreinforced alloy. The wear in terms of height loss was found to increase with the load and sliding velocity. To study the dominant sliding wear mechanism for various test conditions, the worn surfaces were analyzed using optical microscopy.

Keywords- Al-Cu Alloy, Al₂O₃ Particulates, Wear, Worn Surface, Metal Matrix Composites.

I. INTRODUCTION

Metal matrix composites (MMCs) are a class of materials with potential for a wide variety of structural and thermal management applications. Metal matrix composites are capable of providing higher temperature operating limits than their base metal counterparts, and can be tailored to give improved strength, stiffness, thermal conductivity, abrasion resistance, creep resistance or dimensional stability [1, 2]. Unlike resin matrix composites, MMCs are nonflammable, do not outgas in a vacuum and suffer minimal attack by organic fluids such as fuels and solvents.

The principle of incorporating high performance second phase into a conventional engineering material to produce a combination with features not obtainable from the individual constituents is well known. In MMC, the continuous or matrix phase is a monolithic alloy, and the reinforcement consists of high performance carbon, metallic or ceramic additions.

Most of the commercial work on MMCs has focused on aluminium as the matrix metal. The melting point of aluminium is high enough to satisfy many application requirements, yet low enough to render composite processing reasonably convenient. Also, aluminium can accommodate a variety of reinforcing agents [3, 4].

Reinforcements, characterized as either continuous or discontinuous, may constitute from 10 to 70 vol. % of the composite. A continuous fiber or filament reinforcement for aluminium includes graphite, silicon carbide, boron and aluminium oxide. Discontinuous reinforcements consist mainly of SiC in whiskers form, particle types of SiC or Al₂O₃ and short or chopped fibers of Al₂O₃ or graphite.

Incorporation of particulates improves the wear resistance, damping properties, hardness and stiffness [5]. 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 along with SiC and Al₂O₃ provide intrinsic lubricity. MMC materials have been engineered to provide exceptional wear resistance and represent an important family of applications.

Although much of the early work on Al-MMCs concentrated on continuous fiber types, most of the present work focused on discontinuously reinforced Al-MMCs because of their greater ease of manufacturing, lower production costs, and relatively isotropic properties difference. In MMCs mechanical properties depend on the amount, size, shape and distribution of the dispersed phase apart from the mechanical properties of the matrix material, and on the nature of the interface. Processing methods for discontinuous Al-MMCs include stir casting, squeeze casting, liquid metal infiltration, spray deposition, powder metallurgy and extrusion. Among the variety of manufacturing processes available for particulate matrix composites, stir casting is generally accepted as a promising route because of its simplicity, flexibility and applicability to large quantity production [6, 7]. In the present investigation Al-4.5 wt. % Cu alloy is used as the matrix material and Al₂O₃ particulates are used as the reinforcement. Al₂O₃ reinforced Al-Cu composites are fabricated by stir casting method by varying weight percentages as 2 and 4. Dry sliding wear test is conducted on as cast Al-4.5Cu alloy and its composites to know the effect of load and sliding velocity on wear behavior by using pin on disc wear testing machine.
II. MATERIALS AND EXPERIMENTAL DETAILS

2.1. Raw Materials
For fabrication of Al-4.5Cu – Al₂O₃ microcomposites, Al-4.5Cu alloy was used as the matrix. Micro Al₂O₃ particles with the average size of 80-100 microns used as the reinforcement particulates.

2.2. Synthesis of Composite Materials
Stir casting is a primary process of composite production in which in which continuous stirring of molten base metal is done followed by introduction of reinforcements. The first process in the experiment is preheating. Here, the empty crucible and the reinforcement powder, namely Alumina heated to a temperature close to that of the main process temperature. The melting of Al-4.5Cu alloy is carried out in the graphite crucible inside the furnace at a temperature of 750 degree Celsius. The furnace completely melts the pieces of aluminium alloy. The degasser removes all the trapped gases from the melt in the crucible and ensures that the temperature of the mixture in the crucible does not get transferred easily to the atmosphere. The stirring mechanism is lowered into the crucible inside the furnace and set at the required depth. The vigorous automatic stirring of the material takes place for 5 min with 300rpm stirring rate. Further, calculated amount of Al₂O₃ particulates added into the molten Al-4.5 Cu alloy at a constant feed rate. The pouring was done at a temperature of 730 degree Celsius into a preheated cast iron permanent mould of dimensions 125mm x 15mm. The die was released after few minutes and the cast specimens were taken out.

2.3. Microstructure and Dry Sliding Wear Test
Metallographic test samples of 5mm thickness were obtained by cutting the as cast and Al-4.5Cu-Al₂O₃ composites. They were polished as per the standard metallographic procedure and etched with Keller’s reagent. The microstructure was observed using a metallurgical optical microscope. The dry sliding wear behavior of Al-4.5Cu-Al₂O₃ composites was evaluated using a pin-on-disc wear apparatus at room temperature according to ASTM G99 standard. Pins of length 25mm and diameter 8mm were prepared from the cast samples. The experiments were conducted at a constant sliding velocity of 1.413m/sec and sliding distance of 2000m over a varying load of 10N, 20N, 30N and 40N. Similarly experiments were conducted at a constant load of 30N and sliding distance of 2000m over a varying sliding speed of 0.942, 1.413 and 1.884 m/sec. The polished surface of the pin was slid on a hardened chromium steel disc. A computer aided data acquisition system was used to monitor the loss of height. Wear value is presented in terms of height loss in micrometer. Fig. 1 shows the wear test machine used to conduct the experiments.

III. RESULTS AND DISCUSSION

3.1. Microstructure

Fig.1. Wear test machine (rotating steel disc and pin holder)

Fig.2. Showing the optical micrographs of (a) as cast Al-4.5Cu alloy (b) Al-4.5Cu-2 wt. % Al₂O₃ (c) Al-4.5Cu-4 wt. % Al₂O₃ composites
3.2. Wear Mechanism

Fig. 3 shows the comparison of wear in terms of height loss of the Al-4.5Cu alloy and Al-4.5Cu-Al₂O₃ composites. Wear tests were conducted at a constant sliding velocity of 1.413 m/sec and sliding distance of 2000 m over a varying load of 10N, 20N, 30N and 40N. It is clear that with the addition of Al₂O₃ particles to the alloy, the material exhibits a lower height loss. The increase in the wear resistance can be attributed to the strengthening of the Al-4.5Cu matrix due to the Al₂O₃ reinforcement, which results from an increase in the dislocation density as the percentage of reinforcement increases from 2 to 4 wt. %. Also it could be seen that the wear in height loss increases as the normal load increases from 10N to 40N. At higher loads the contact surface temperature increases. By measuring the height loss as a function of applied load, it has been reported that a critical load exists below this load, where wear is mild and steady; above this load a severe wear occurs [8,9].

Fig.4. Showing the wear in terms of height loss for Al-4.5Cu alloy and its composites at constant load of 30N and varying sliding velocities

Sliding velocity is another important influencing factor for wear behaviors according to Fig. 4. It is clearly indicating as sliding velocity increases from 0.942 m/sec to 1.882 m/sec, there is a more height loss. Due to friction between the specimen and the rotating disc during dry sliding, temperature rises at higher velocities leading the specimen to lower its mechanical property. The rise in the temperature was noticeable as the sliding velocity was increased, which causes a negative effect on the performance of specimen [10, 11]. As the temperature rises, the bonding within the matrix begins to fail, leading to severe wear and further changing to delamination with further increase in velocity. In the case of Al-4.5Cu-Al₂O₃ composites height loss was less compared to base Al-Cu matrix alloy. During wear process for composites, the smeared reinforcements were fragmented and crushed between the rotating disc, forming a protective layer.

Fig.5 (a-b) Show the worn out surfaces of Al-4.5Cu alloy and Al-4.5Cu alloy reinforced with 4 wt. % of Al₂O₃ composites respectively at a sliding velocity of 1.884 m/sec, sliding distance of 2000 m and at 40N applied load. From fig. 5a it is evident that the surface of alloy is rough with deep grooves compared with the composite specimen (fig. 5b) with fine grooves. Due to the applied load of 40N load and sliding speed 1.884 m/sec, the morphology shows that the Al-Cu alloy has experienced severe wear under the absence of Al₂O₃ reinforcements. The Al-Cu-4 wt. % Al₂O₃ composites show smooth surface due to presence of Alumina that protecting the specimen from direct contact with the disc, thus enhancing the wear resistance.

Fig.5. Optical micrographs of the worn surfaces of (a) as cast Al-4.5Cu alloy (b) Al-4.5Cu-4 wt. % Al₂O₃ composite
CONCLUSIONS

In this research, the processing and wear behavior of Al-4.5Cu alloy based composites reinforced with 2 and 4 wt. % of Al₂O₃ particulates were investigated. Al-4.5Cu alloy with 2 and 4 wt. percentages of Al₂O₃ particulates composites were fabricated by stir casting method. Optical micrographs revealed the uniform distribution of Al₂O₃ particulates in Al-Cu alloy matrix material. Wear in terms of height loss was more in the case of base matrix and it was decreased as the weight percentage of reinforcement increased from 2 to 4 wt. percentages. Applied load and sliding velocities played important role in wear behavior of as cast Al-4.5Cu alloy and its composites. As applied load and sliding velocities increases from 10N to 40N and 0.942m/sec to 1.882 m/sec, there was increase in height loss of both as cast and its composite specimens. Further, height loss was lesser in the case of Al-Cu-Al₂O₃ composites.

REFERENCES


