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Evaluation of Tribological Properties of Aluminium-SiC-B4C Hybrid Composites

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A B S T R A C T

Metallic materials are employed in most of the engineering applications involving dynamic and thermal load conditions. Different alloys of steel have been employed in industries normally owing to their higher strength, toughness and thermal properties. However, some of the technological applications demand materials with lower density, possessing suitable strength and thermal properties. Aluminium alloy is one such material with lower density and higher corrosion resistance properties compared to structural steels. The tribological properties of aluminium can be further enhanced by the addition of the ceramic materials like SiC, Al2O3, TiC, B4C etc, which have superior wear resistance characteristics. Based on the research work being carried out in the field of composite material an attempt is made to evaluate the changes in the tribological properties due to the hybrid reinforcement of material consisting of Al6061 as base alloy, SiC and B4C as reinforcement processed by stir casting method for 10% reinforcement with a combination of (2%SiC+8% B4C, 4%SiC+ 6% B4C, 6%SiC +4% B4C & 8%SiC +2% B4C). Tribological Test is being carried out with varying parameters of Load (10N to 60N), Sliding Distance (5000m) for a Constant Speed (2m/sec) for the processed materials.

1. INTRODUCTION

Metal matrix composite is a new class of material, whose mechanical and tribological characteristics are influenced by large number of factors, which includes material, processing as well as operating parameters. The mechanical and structural characteristics of MMCs can be tailored to meet specific applications by suitable selection of these parameters. With increasing demand for high performance materials in advanced technological applications, there is need for persistent investigations to be carried out to study the influence of various parameters on the behavior of this class of material. Tribological properties of materials depend upon the structural features, which in turn depend upon the techniques and parameters involved in processing of the material [1]. Hence it is a challenging task for design engineers to analyse the tribological characteristics of metal matrix composite materials prepared by primary and secondary processing techniques.

Many of the components made out of MMCs are involved in applications, where the surfaces of the component experience relative sliding and/or rolling motion with respect to the surfaces of the matching components [2]. The tribological properties of these components are important in order to achieve higher performance characteristics of the system. The present work is a small attempt to analyse the influence of some of these parameters on tribological characteristics of Al-SiC-B_4C based hybrid MMCs.

2. LITERATURE SURVEY

Substantial literature has been studied on composite materials, few of them are present in this section.

Researchers produced Al with varying volume of TiC composite by stir-casting route. The process variables such as preheating temperature of particles, melt temperature, stirring speeds etc., were considered for fabricating composites and the Al/B_4C MMCs exhibited superior properties [3].

Many mechanical components, processed using metal matrix composites are subjected to applications, where they experience relative motion with the mating components. The performance of the mechanical system depends upon the tribological characteristics of the components involved in such situations. Tribology deals with science and engineering of surfaces which are in contact and have relative motion with respect to each other [4].

Investigations are performed on Aluminum MMCs used in brushes, bearing material, contact strips etc that are operated at elevated temperature conditions and wear behavior of these composite have been tested. Results obtained indicate that incorporation of ceramic reinforcement particles improves the seizure resistance of the composite at elevated temperature with respect to pure alloy. Results also indicate that increase in volume fraction of reinforcement reduces the wear losses of composite materials [5].

Tribological properties of composites play vital role where surfaces are in contact with relative motions. Researchers have investigated on tribological properties of composites and listed the factors which influence these properties. The main factors are

1. The type of matrix and its structural features.
2. Reinforcement type, their size, shape and volume percentage.
3. Operating conditions like speed, temperature, load, type of relative motion, lubrication and environment [6].

Two-body sliding wear tests carried out on the aluminium composites under varying load conditions indicate that specimens of base alloy underwent large wear which increased almost linearly with load. With further increasing normal load, the specimens attained severe wear from mild wear. Similar wear trends were observed for the reinforced specimen but the wear rates were comparatively less than that for the base alloy. For Aluminum based MMCs increased load leads to sever wear by changing wear mechanism from abrasion to delamination due to cracking of reinforcements at subsurface region [7]. Leave one clear line before and after a main or secondary heading and after each paragraph.

3. OBJECTIVES

Objective of the present study which are taken from the literature review are listed below:

- Selection of Matrix and Reinforcement materials.
- Composite material processing, Al6061 with SiC and B_4C (2,4,6,8%) by Stir Casting.
- Sample preparation for SEM and Tribology test.
- Evaluation of Tribological Property of the processed materials with varying the tribological parameters.

4. EXPERIMENTAL WORK

The experimental work required to accomplish the above said objectives are discussed in detail.

4.1 Selection of matrix material (aluminium 6061) and reinforcement materials

It's the predominant material in the series which consist of SiC in the higher range. This material is widely used due to its superior benefits ranging from its strength to thermal conductivity. These materials are best suited even to carry out secondary process. The presence of SiC makes the material harder compared to other series of the materials. When the present grade material is reinforced with additional amount of SiC, the strength will be further enhanced but care should be taken such that the brittleness phenomenon is not being incorporated due to higher percentage of SiC. Further heat treatment can also be carried out to alter the thermal conductivity properties of the material which can be used in many applications.

In the present work SiC and B_4C particle (30μm) is added as reinforcement material along with Al6061 matrix material for a weight percentage of 2%, 4% 6% and 8%, processed by liquid stir processing technique which is normally termed as Stir casting process. Overall percentage is selected upto 10% with appropriate portion of matrix material. Table 1 shows the details of the percentage of reinforcements used in the present study.

Table 1. Percentage of reinforcements.

	Al6061	SiC	B_4C
Sample 1	100%	-	-
Sample 2	90%	2%	8%
Sample 3	90%	4%	6%
Sample 4	90%	6%	4%
Sample 5	90%	8%	2%

The materials are processed by the stir casting process wherein the preheated reinforcement particles were added to the molten aluminium material. The evaluation of mechanical properties is carried out by preparing the samples as per the ASTM standards. Tensile test sample is prepared as per ASTM B557 standards, Tribological test sample is prepared as per the ASTM G99 standard.

The Tribological test is being carried out on the Pin on Disc test apparatus with varying load parameters ranging from 10N to 60N, Sliding distance is kept constant for 5000m with a constant speed of 2m/sec. The details of the equipment is shown in Figure 1. The details of the samples is shown in the Figure 2. Table 2 shows the details of pin on disc apparatus process parameters.

Fig. 1. Pin on Disc apparatus.

Fig. 2. ASTM G99 standard pin.

Table 2. Process parameters of Pin on Disc Test.

Speed	2 m/sec
Load Range	10 – 60 N
Sliding Distance	5000m
Disc Size	Diameter 120 mm ×Thickness 8 mm
Disc Material	EN32 hardened steel disc (65HRC) and Ra of 2.5–3.5 μm
Pin Size	10mm diameter and 28mm length

5. RESULTS & DISCUSSIONS

5.1 Tribological test results

Results obtained indicates that, increase in sliding distance leads to increase in wear loss for all the load conditions. In most of the cases, the slope of the curves is observed to be higher at the initial conditions which indicates running-in wear leading to asperity contacts that take place resulting in increased wear rates. At later state, the slope of the wear curves reduces due flattening of asperities, increase in contact area. Further increase in sliding distance increases the wear rate due to the abrasive nature of reinforcement particles that gets entrapped between the surfaces in contact.

It can be noted from the Fig. 3 to Fig. 7 that the as the load increases from 10N to 60N wear rate also increases. Sample 1 consists of only base material Al6061, it has experienced higher wear rate compared to the reinforced materials. The Sample 4 (6%SiC+4%B_4C) has lesser wear compared to other percentages. The presence of hard reinforcements leads to reduced wear rete of the material.

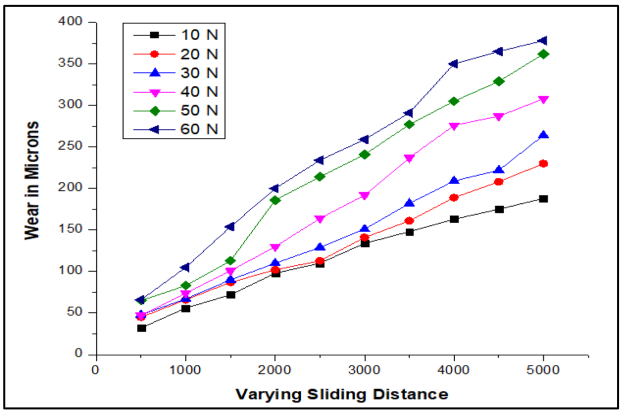

Fig. 3. Sample 1 V/s sliding distance.

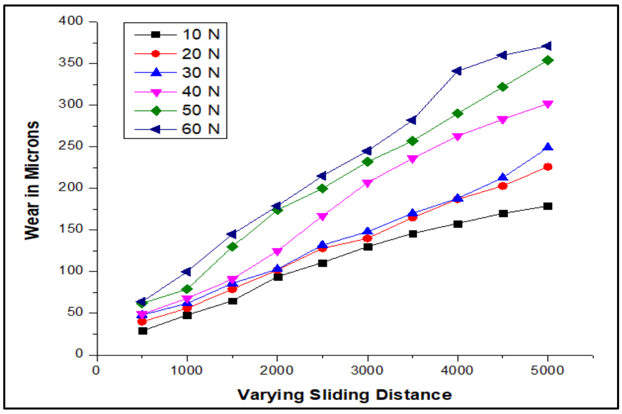

Fig. 4. Sample 2 V/s sliding distance.

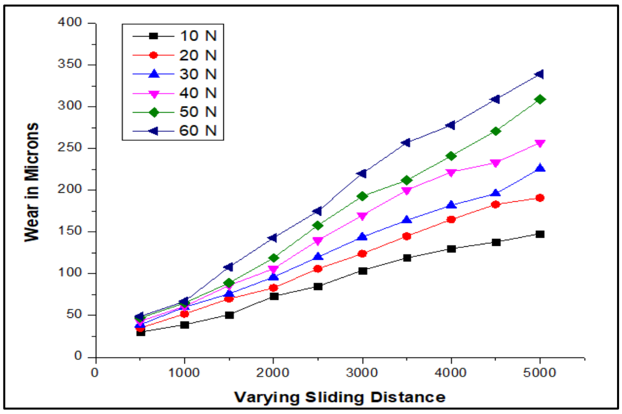

Fig. 5. Sample 3 V/s sliding distance.

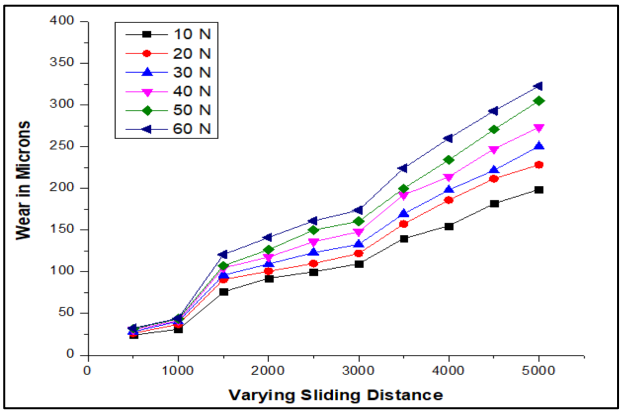

Fig. 6. Sample 4 V/s sliding distance.

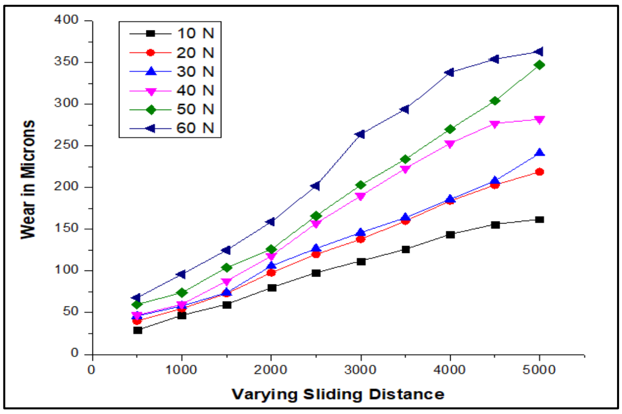

Fig. 7. Sample 5 V/s sliding distance.

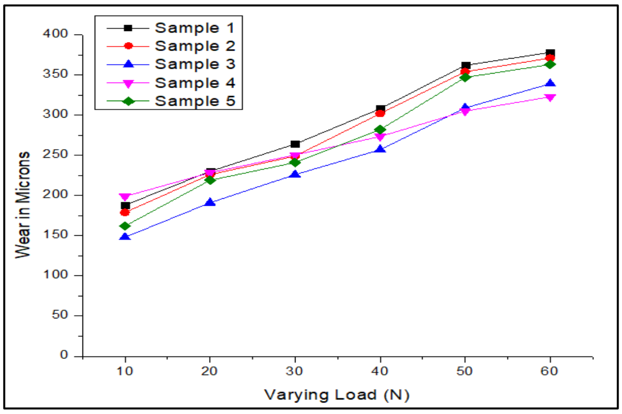

Fig. 8. Wear v/s varying load (N).

The wear loss of test specimens under various normal load circumstances is shown in Fig. 8. With increasing normal load, it has been observed that wear loss of all materials increases. With an increase in the proportion of reinforcing particles, it is discovered that the wear losses in the test specimens reduce. The wear loss of the material is decreased by the large number of reinforcing particles, which provide better resistance to dislocation movement and subsequently to the plastic deformation of the material.

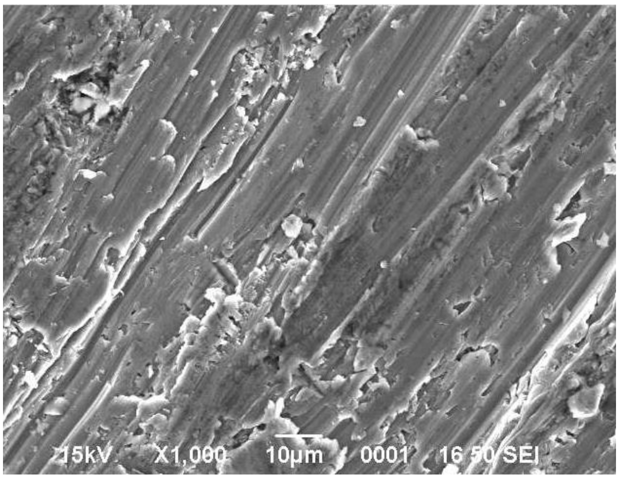

Fig. 9. SEM of Al6061 worn out surface.

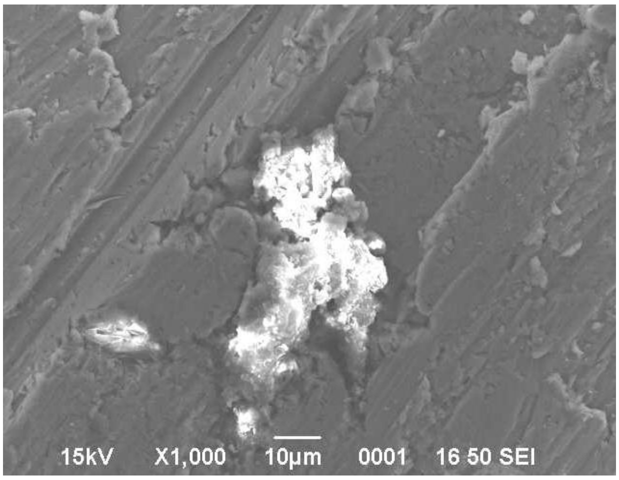

Fig. 10. SEM of Al6061+6%SiC+4%B_4C worn out surface.

The SEM pictures of the worn surface of the cast Al6061 specimen subjected to sliding wear are shown in Figure 5.9. The illustration shows how the material's plastic deformation results in the development of grooves that run in the direction of sliding. Where materials have been pulled out, there are some craters that can be seen. Asperities of the mating surfaces suffer a make-or-break situation during dry sliding wear, where they temporarily stay together, go through elastic/plastic deformation, and then separate. Subsurface fissures that may already exist or that form as a result of the produced stress during this process have the potential to spread and reach the surface, where the removed material manifests as craters. Fig 10 shows the presence of the reinforcement material which is embedded in the matrix material, presence of these reinforcement material helps in wear reduction.

6. CONCLUSIONS

The preliminary investigations lead to the following conclusions:

A 5000m sliding distance wear test shows that the reinforced materials have better wear resistance qualities than the basic materials, which wear out more quickly. Results show that under all load circumstances, an increase in sliding distance causes an increase in wear loss. The wear loss of the material is decreased by the large number of reinforcing particles, which provide better resistance to dislocation movement and subsequently to the plastic deformation of the material.

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