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Study on Wear Nature of Aluminum 7075 Hybrid Metal Matrix Composite

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A B S T R A C T

Aluminum 7075 alloy has garnered significant attention in various engineering applications due to its excellent strength-to-weight ratio and high corrosion resistance. In recent years, the incorporation of reinforcing fibers into aluminum matrices has emerged as a promising approach to enhance mechanical properties, including wear resistance. This study investigates the wear behavior of Aluminum 7075 composite reinforced with varying weight percentages (2%, 4%, and 6%) of boron carbide particles and 2% E-Glass short fibers. The composites were fabricated using the stir casting method, followed by heat treatment to optimize microstructure and mechanical properties. Wear tests were conducted using a pin-on-disc apparatus under dry sliding conditions, with parameters such as applied load, disc speed, and abrading distance being controlled. The wear surfaces were examined through scanning electron microscopy (SEM) analysis of worn surfaces. Results revealed that the addition of reinforcement particles effectively improved the wear resistance of the composite, with the 6% reinforcement exhibiting the highest resistance to wear.

1. INTRODUCTION

Metal matrix composites (MMCs) represent an exciting edge in materials science, where their mechanical and tribological attributes are influenced by an assembly of factors covering material composition, processing methodologies, and operational conditions. These intricate interplays offer a versatile palette for tailoring MMC properties to suit diverse applications. In the quest for high-performance materials crucial for cutting-edge technological demands, a steadfast commitment to ongoing exploration is imperative. It's essential to delve into the nuanced influence of various parameters on MMC behavior to unlock their full potential.

The tribological performance of materials centers on their underlying structural intricacies, intricately linked to the processing techniques and parameters applied. Consequently, deciphering the tribological characteristics of

MMCs crafted through both primary and secondary processing routes presents a formidable challenge for design engineers. Navigating this intricate landscape demands a fusion of expertise, innovation, and relentless inquiry to harness the full capabilities of these advanced materials for a numerous of applications [2].

The utilization of Metal Matrix Composites (MMCs) extends to applications where components undergo sliding or rolling motions relative to matching surfaces. Understanding the tribological behavior of these components is paramount to enhancing system performance. This study represents a modest effort to investigate the impact of select parameters on the wear behavior of Al7075-E-Glass-B_4C hybrid MMCs.

2. SURVEY OF LITARATURE

Extensive research has been conducted on composite materials, with a selection of related literature provided in this section.

To achieve cost-effectiveness in producing particulate reinforced metal matrix composites (MMCs), the stir casting technique was used for the fabrication of AMMCs. The distribution of the reinforcement material within the base material was facilitated by the stirrer. The melting process was carried out within a temperature range of 600–800 ∘ C. Reinforcement particles were poured into the region of the vortex formed by stirring to ensure a homogeneous distribution of particle materials within the base matrix [3].

Researchers opted for Stir Casting technique due to its cost-effectiveness. During fabrication, reinforcements were preheated and gradually introduced into the molten metal. Continuous stirring at 300 rpm for 5 minutes ensured the uniform dispersion of reinforcement particles within the molten metal. Subsequently, the molten metal was poured into a preheated steel mold at 760 ºC and allowed to solidify. This study focused on fabricating LM14 aluminium alloy and 5% boron carbide MMC using the stir casting method and investigating its tribological performance. Various parameters, including loads ranging from 10N to 30N, sliding distances from 1000 M to 2000M, and velocities from 1 m/s to 3m/s, were analysed. Results indicated that enhanced the tribological behaviour of the composite due to formation of tribo layer [4].

As per ASTM G99 standard using Pin on Disc Wear Test, composite specimens of Aluminium 7075, reinforced with SIC for various reinforcements such as zero, one, two, three and four percentage by weight were conducted wear test to obtain required tribological properties. The results shown that increase in reinforcement increased the hardness, it was also observed that weight percentage of silicon carbide increment reduced the wear rate [5].

3. OBJECTIVES

Objectives of this comprehensive study is aimed at understanding the tribological properties of Al7075 composites reinforced with E-Glass and B_4C particles, with a focus on the processing techniques and material characteristics.

- Matrix and Reinforcement Materials selection
- Composite Material Preparation- Al7075 with E-Glass(2%) and B_4C (2, 4, 6%) by Stir Casting
- Sample Preparation for SEM and Tribology Test
- Evaluation of wear Property of the Processed Materials with Varying Tribological Parameters

4. EXPERIMENTAL WORK

The dominant material within the series primarily comprises Boron carbide, particularly in the higher range. B_4C stands out for its array of advantageous properties, spanning from exceptional strength to excellent thermal conductivity. These materials are well-suited even for secondary processes. The inclusion of B_4C renders the material notably harder compared to other series within the materials spectrum.

When the current grade of material is fortified with an increased quantity of B_4C, its strength undergoes further enhancement. However, it is imperative to exercise caution to prevent the introduction of brittleness resulting from a higher percentage of B_4C.

In this study, E-Glass fibres (chopped) and B_4C particles (with a size of 45μm) are incorporated as reinforcement materials alongside the Al7075 matrix material. The weight percentages of these reinforcements range from 2% to 6%, with increments of 2%, and are processed using the casting methodology. The overall fraction of reinforcements is capped at 8%, ensuring an appropriate balance with the matrix material. Table 1 provides a comprehensive overview of the reinforcement percentages utilized in the current investigation.

Table 1. Reinforcements Percentage.

	E-Glass%	B_4C%	Al7075 %
Sample A	0	0	100
Sample B	2	0	98
Sample C	2	2	96
Sample D	2	4	94
Sample D	2	6	92

The materials undergo processing via the stir casting technique, a method involving the addition of preheated reinforcement particles to the molten aluminum material. Following this procedure, the evaluation of properties is conducted in accordance with ASTM standards, ensuring consistency and reliability in the assessment process. The tribological test samples are meticulously prepared in accordance with the ASTM G99 standard, ensuring adherence to established protocols and methodologies for consistent and standardized testing procedures.

Fig. 1. Pin on disc apparatus.

Table 2. Wear test process parameters.

Speed	1m/s -3m/s
Load	15N
Abrading Distance	1000M
Pin size	10 mm diameter, 30 mm length
Disc Material	EN32
Radius of Rotation	7cm

Fig. 2. Test samples.

5. RESULTS AND DISCUSSIONS

5.1 Wear Test Results

The findings reveal a consistent trend, as sliding distance increases, wear loss intensifies across all speed conditions. Notably, initial stages exhibit steeper curves, indicative of running-in wear characterized by increased asperity contacts. This initial phase witnesses increased wear rates. Subsequently, as the process progresses, wear curves demonstrate a gradual decline in slope, attributed to the reduction in asperities and an expansion in contact area. However, as sliding distance persists, wear rates surge once again, attributed to the abrasive nature of reinforcement particles trapped between the contacting surfaces.

It is observed in the Fig. 3 to Fig. 8 that increase in speed results in increase in wear under all speed conditions. Base aluminium material has shown limited resistance to wear under loading condition and increased speed condition compared to aluminium with reinforcements. Least wear loss is observed in sample 5 that is aluminium hybrid composite with 2% E-glass and 6% boron carbide. Presence of hard particles of reinforcements leads to increased wear resistance compared to composites with less reinforcement particles. The investigation revealed a notable reduction in wear losses within the test specimens. This decline in wear loss can be attributed to the abundant presence of reinforcing particles. These particles play a crucial role in enhancing resistance against dislocation movement, thereby mitigating the occurrence of plastic deformation within the mater.

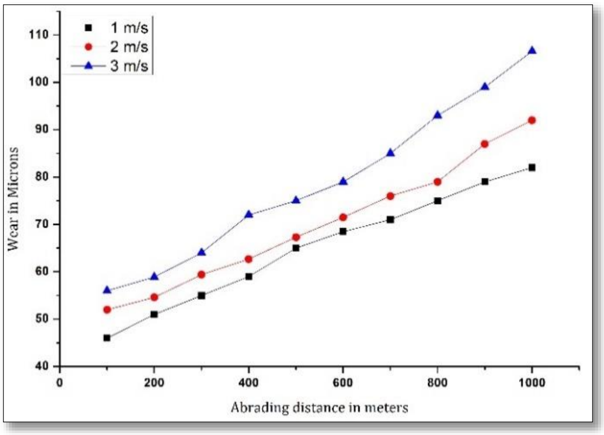

Fig. 3. Sample A: Wear v/s Abrading distance.

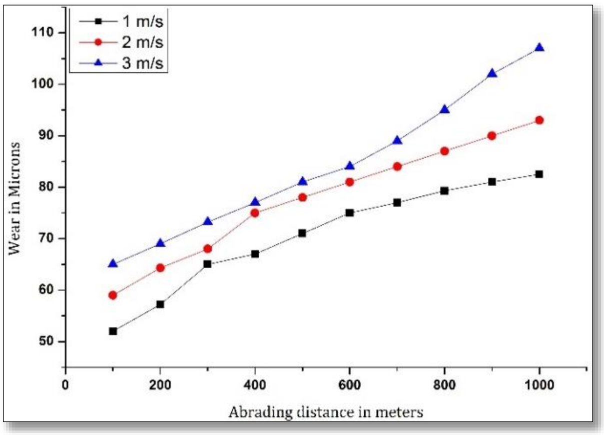

Fig. 4. Sample B: Wear v/s Abrading distance.

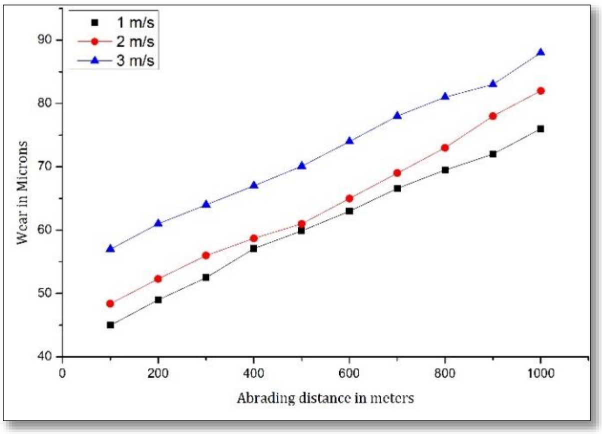

Fig. 5. Sample C: Wear v/s Abrading distance.

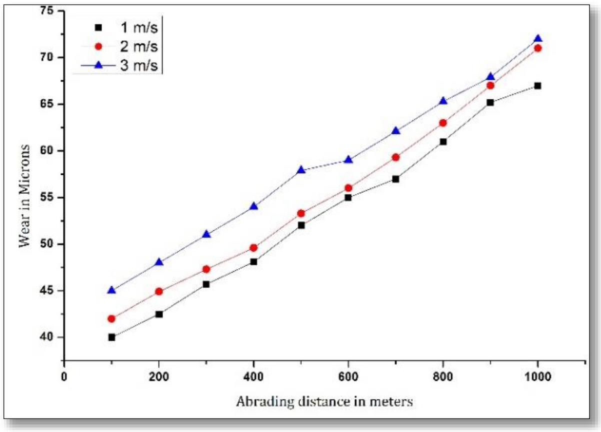

Fig. 6. Sample D: Wear v/s Abrading distance.

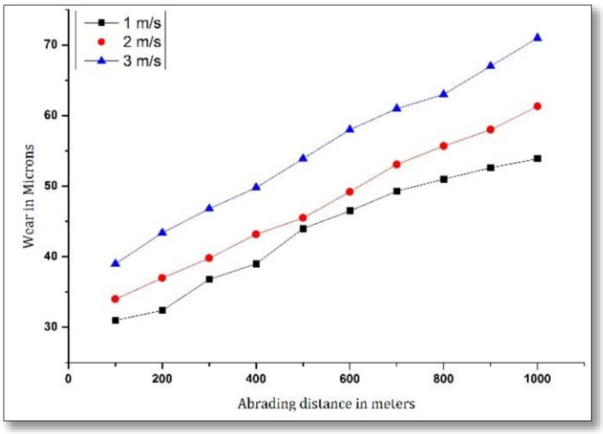

Fig. 7. Sample E: Wear v/s Abrading distance.

5.2 SEM Results

The SEM images in Fig. 8 depict the worn out surface of the MMC Al7075 with E-Glass fiber 2% and 6% boron carbide specimen under sliding wear conditions. These images reveal how the material undergoes plastic deformation, leading to the formation of grooves aligned with the direction of sliding. Additionally, there are visible craters where material has been pulled out. During dry sliding wear, the asperities on mating surfaces experience a critical situation where they either remain in contact or separate. This process involves elastic and plastic deformation before eventual separation. Subsurface fissures, either pre-existing or formed due to stress, have the potential to propagate and reach the surface. This propagation results in the formation of craters as material is removed from the surface.

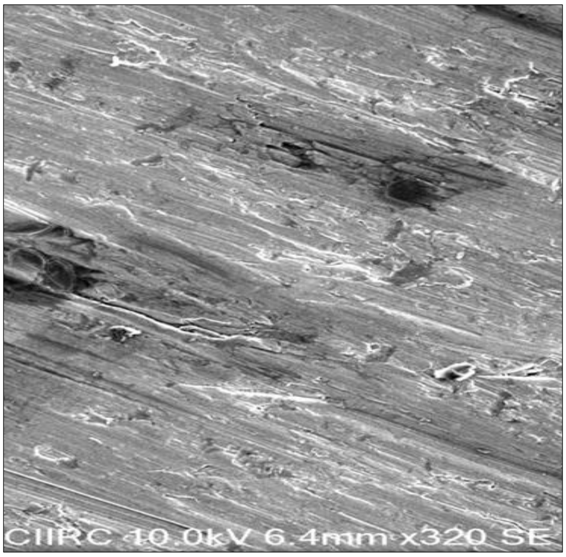

Fig. 8. SEM of worn out surface of Sample E.

6. CONCLUSIONS

The initial findings from the preliminary investigations suggest the following conclusions:

In a wear test with constant load of 15N, spanning 1000 meters of sliding distance conducted for low speeds of 1.2 and 3m/s, it becomes evident that the reinforced materials exhibit superior wear resistance compared to the basic material, which demonstrate faster wear rates. Regardless of the applied load, wear loss increases with extended sliding distances. However, the presence of numerous reinforcing particles notably mitigates wear loss by impeding dislocation movement and, consequently, reducing the plastic deformation of the material.

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