



Dry sliding Wear Behavior Aluminum 2219 MMC reinforced with Boron carbide & Molybdenum disulphate

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Abstract

BC 10% boron carbide and 5% molybdenum disulphate particles are used to strengthen aluminum (Al-2219). Stir casting is used to create aluminum alloy hybrid metal matrix composites (HMMCs). Pin-on-disc equipment is used to perform dry sliding wear tests on pure base alloy Al-2219, mono, and hybrid composites at room temperature. Sliding speed, sliding distance, and applied stress were among the factors used to examine the wear behavior of composites. The outcome demonstrates that wear rate increases as load and sliding distance increase. Compared to monocomposite materials, hybrid composites have greater wear resistance. SEM was used to examine the worn-out surface.

Introduction

Compared to monolithic alloys, Metal Matrix Composites (MMCs) offer a number of benefits. Compared to unreinforced aluminum alloy, aluminum alloy matrix composites reinforced with hard ceramic particles have superior mechanical qualities such specific strength, specific modulus, and increased wear resistance [1]. Hybrid metal matrix composites, or HMMCs, are widely used in the automotive, marine, and aerospace industries. MMCs have become cutting-edge materials that allow engineers to modify the tribological and mechanical characteristics. Liquid metallurgy is one of the easiest and most cost-effective ways to fabricate MMCs, and it also distributes the reinforcing particles uniformly throughout the soft aluminum matrix. [2] Ceramic particle reinforcement results in improvements in fatigue, creep, strength, and stiffness. B₄C has better mechanical qualities than SiC and Al₂O₃ because it has a lower density and a higher hardness, even at high temperatures [3]. Graphite and molybdenum disulfide are the two primary categories of solid lubricants. Compared to liquid and oil-based lubricants, these lubricants can tolerate higher temperatures. In tribological applications with the lowest coefficient of friction, graphite can resist oxidizing temperatures of up to 350 °C. [4,5] Based on the current literature review many study has been carried out.

The information on the impact of different types of reinforcement, their size and volume proportion, and their aging behavior with Al-based MMCs is included in this review of the literature. A variety of aluminum alloys and reinforcing types, including Sic [[11], [12], [13]], B4C [[14], [15], [16]], Al₂O₃ [17,18], Gr, etc., are available in various diameters, morphologies, and volume fractions. Large composite systems can be created by combining these reinforcements with diverse matrices using a variety of processing techniques, including powder metallurgy, stir-casting [19], squeeze casting, hot extrusion, etc. In addition to cheaper operating and maintenance costs, composite structures have continuously shown savings of at least 20% over their metal equivalents [20].

Any relative motion in any element, including cylinder bores, connecting rods, brake rotors, reciprocating and rotational piston motions, etc., frequently results in wear. In order to guarantee improved and reliable performance in any tribological application, wear is an essential factor to take into account while creating these kinds of components [21,22]. It is now widely acknowledged that MMCs exhibit superior wear characteristics as well as high fundamental strength and stiffness when compared to their respective monolithic alloys. In these situations, a comparison of the wear behaviors of leaded copper alloy and graphite-reinforced lead-free copper alloy has been discovered [23]. In both high-stress and low-stress abrasive wear circumstances, the particle-reinforced MMC's abrasive wear resistance rises as the volume fraction of particles increases [24].

In a similar vein, the alumina and zircon sand particles that have been used with the microstructures of the composites under as-cast conditions exhibit a consistent particle distribution and demonstrate improved bonding in the zircon particle reinforced composite [25]. The dry sliding wear behavior of alloys of hybrid MMCs, such as AL 6082 reinforced with red mud particles [26], with lithium and silicon nitride [4], graphite/fly ash reinforced aluminum (Al6Mg) [27], hot-extruded Al6061/Si₃N₄/Cf [20], the high-temperature wear behavior of Al₂219/n-B₄C/MoS₂ [5], and aged and non-aged SiC-reinforced AlSi₇Mg₂ [28], have all been reported using an experimental approach. Additionally, the mechanical/machining properties of Al₂219/n-B₄C/MoS₂ [30] and the impact zscxxx of replacing TiC with SiC in different ratios in Al-5052/TiC/SiC [19]. The experiments were conducted, and investigations were made with optical microscope [15], SEM [21,22,], XRD and other methods [9,22,]

We learned from the literature mentioned above that Al-B 4C and Al-B₄C-Gr have received less attention. This research examines the wear behavior of Al₂219, Al₂219+8%B₄C, and a hybrid composite (Al₂219+10%B₄C+5%MoS₂) using a pin-on-disc wear machine. Stir casting is a two-step process used to create composites. By taking into account load, sliding distance, sliding velocity, wear rate, and wear loss, the impact of boron carbide on mono and hybrid composites was examined. Composites are prepared by two step stir casting technique. The effect of Boron Carbide on mono and hybrid composite were studied by considering load, sliding distance, sliding velocity, wear rate and wear loss were investigated.

Materials & Matrix material

Aluminum alloy 2219 has been used as the matrix material for this article. The automotive and aerospace sectors employ AA 2219 (or AA 2xxx series alloys) because they have a very high tensile strength when properly heated. However, when subjected to harsh operating circumstances, these alloys are prone to wear. Additionally, boron carbide (B₄C), graphite (Gr), and molybdenum disulphide (MoS₂), which are typically employed as filler materials and are known to have superior wear-resistant qualities, were chosen as reinforcing materials. Therefore, it is considered essential to investigate how adding these filler materials to AA 2219 alloy improves its wear-resistant qualities. Therefore, it is considered essential to investigate how

adding these filler materials to AA 2219 alloy improves its wear-resistant qualities. This knowledge serves as the foundation for the selection of the base and filler materials in this manuscript, and the investigations pertaining to these materials' qualities are discussed in the subsections that follow.

Table 1 & 2 shows Chemical composition & physical properties of Al-2219

Table 1. Chemical composition limits of Al-2219.

Weight %	Al	Si	Fe	Cu	Mn	Mg	Zn	Ti	Others
2219	Bal	0.20	0.30	5.80–	0.20–	0.02	0.1	0.02–	0.050–
		Max	Max	6.80	0.40	Max	Max	0.1	0.15

Table 2. Physical properties of Al-2219.

Density	Hardness (Vickers)	Tensile Strength	Melting Point
2.84g/cc	130 HV	290MPa	543-643°C

Tensile strength, density, ductility, formability, workability, weldability, and corrosion resistance must all be taken into account when choosing an alloy for a particular application since pure aluminum metal is too soft. Alloys made primarily of aluminum are known as aluminum alloys. Copper, magnesium, manganese, silicon, and zinc are common alloying elements. In the production of aircraft, alloys primarily made of two lightweight metals, such as magnesium and aluminum, have proved essential. Compared to other aluminum alloys, aluminum-magnesium alloys are lighter and far less combustible than alloys with a high magnesium content.

Aluminum alloys 2219 are known for their use at high temperatures and are an age-hard, copper-containing alloy of aluminum. It was utilized in the initial Space Shuttle Standard Weight external tank and is frequently employed in the production of structural parts for high-temperature, high-strength weldments. Nevertheless, in light of all these concerns, the basis matrix for this study was chosen to be Al-2219 alloy, which was purchased in the form of ingots from Fenfee Metallurgical in Bangalore, India. Later the matrix was prepared to get the testing specimens under controlled conditions in Foundry of Harihar city, India. Fig a & b shows lab samples & equipments



Experimental Setup

Dry sliding wear test is conducted on DUCOM TR-20M-106 wear test apparatus as shown in fig.1 as per ASTM G 99-95 standards wear test is conducted. The wear specimen of 8 mm diameter and 30 mm height was machined from casting .The track diameter of 120 mm radius is fixed in our experiment. The specimen ends are polished with emery paper and cleaned with acetone before and after the test . It was conducted in Davangere at Bapuji Engg College Lab,India.

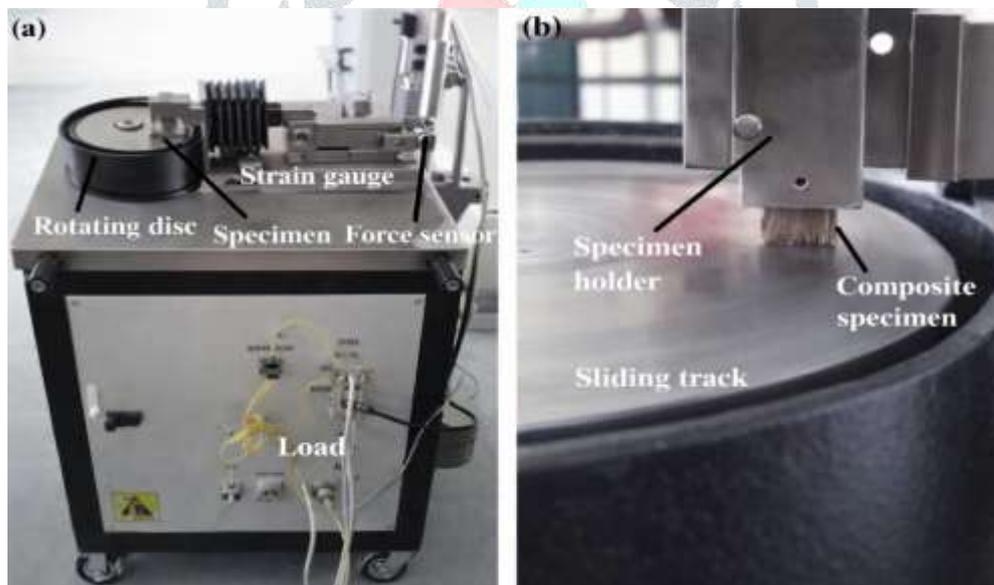


Fig 1 Expt Setup.

Results & Discussion

The Al 2219-B4C–MoS₂-Gr composite's dry sliding wear behavior was examined through studies carried out on a pin-on-disc test rig. The specimens prepared as per ASTM G99 standards are clamped in a specimen holder and held parallel in contact with the counter surface under room temperature. Four distinct levels of each combination were selected using the traditional method. Three weight percentages of aluminum 2219, aluminum 2219-5% Gr, aluminum 2219-5% MoS₂, and aluminum 2219-15% B₄C are used to prepare the samples. The graph (Figs. 5, 6, and 7) below shows how the Al-15% B₄C composite's wear resistance has improved.

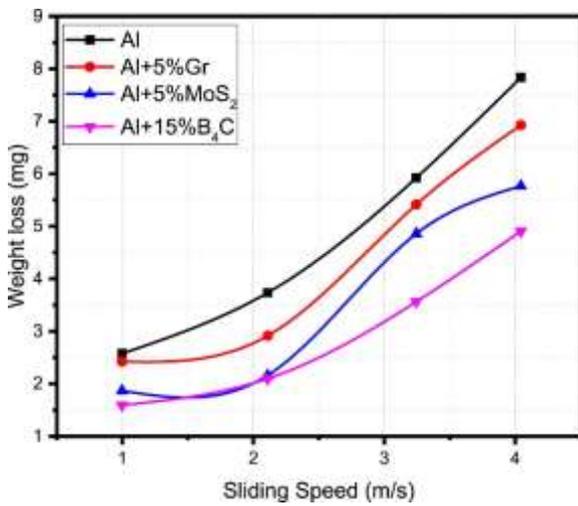


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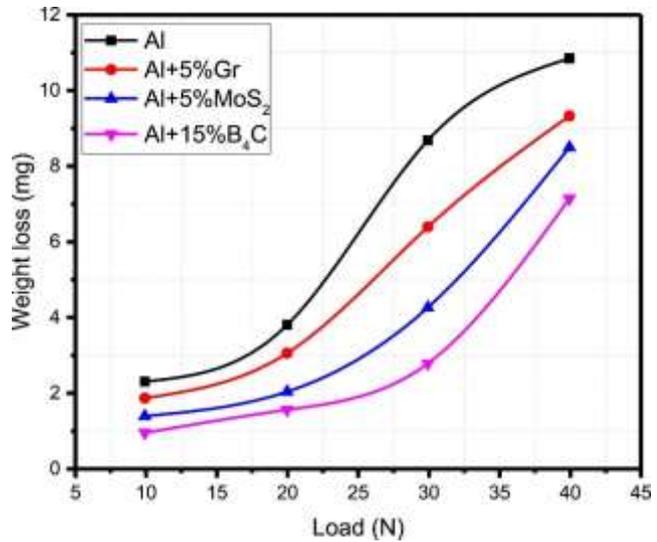


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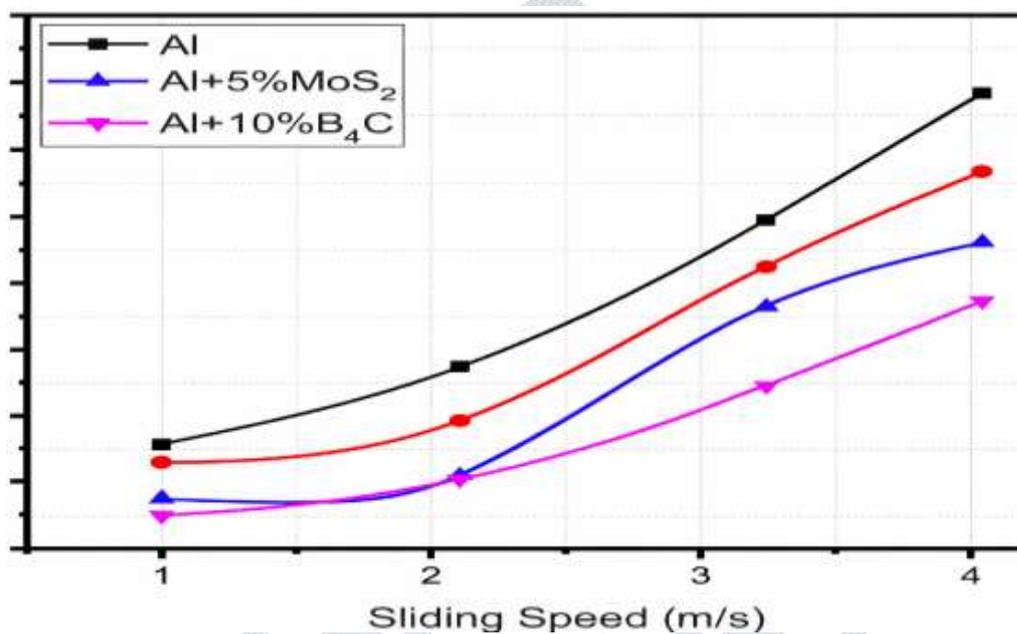


fig.7

Figure 7 shows how sliding distance affects weight reduction for material combination 3.

5.1. The traditional wear test technique

Al 2219-B4C–MoS₂-Gr hybrid MMC wear experiments were conducted using the traditional approach with different chosen parameters. Out of the four constants, two parameters are kept in the set of experiments that yield the findings.

5.1.1. Effect of applied load

Fig. 5 Shows the effect of applied load on weight loss of hybrid composites reinforced with different weight percentages of Al, Al+5% MoS₂, Al+5% Gr, Al+15% B₄C for a constant speed of 2.51 m/s and sliding distance of 600 m.

According to Fig. 5 the variation of weight loss with applied load for a fixed sliding speed of 2.51 m/s and sliding distance of 600 m. Mild wear was observed for a lower range of applied load, but as the load increased up to 20 N, the weight loss of unreinforced alloy and composite increased. As the load increased beyond 20

N, the wear pattern has changed for the reinforced and unreinforced MMC's. In a typical mechanical wear test apparatus, the weight loss in the test sample increases with an increase in the applied load. However (From the graph shown in Fig. 5), it is observed that with an increase in applied load the weight loss in the Al+5% Gr MMC was not as significant as the base alloy and other MMC's. This is since the Gr acts as the solid lubricant facilitating reducing friction, thus reducing wear (weight) loss.

5.1.2. Effect of the sliding speed

Fig. 6 shows the wear loss variation with sliding speed for the unreinforced alloy reinforced with Al+5% MoS₂, Al+5% Gr, and Al+15% B₄C particulates. It is observed from the graph that the wear loss has increased as the sliding speed increases for Al alloy up to 2 m/s. The trend changed as the sliding speed increased, indicating more loss as the sliding rate increased. From the graph, the composite with 5% Gr is found to be less wear loss till the two m/s. The Gr acting as the solid lubricant further shows that the wear loss has increased severely. However, the trend for the MoS₂ reinforced composite is slightly different. It is found that still there less wear loss initially, and suddenly, there is an increase in the wear loss. This may be due to the seizure of the solid lubricant layer formed by the MoS₂. Furthermore, as the sliding speed increased to 3.9 m/s, there is diminished wear loss. This may be because the formation of the oxide layer is reached. Whereas in the case of B₄C particulate reinforcement, the wear loss is reduced. This is since the B₄C particulates being harder serve as a protective layer coming first in contact with the counter surface. But the wear loss has increased gradually with a lower rate of wear.

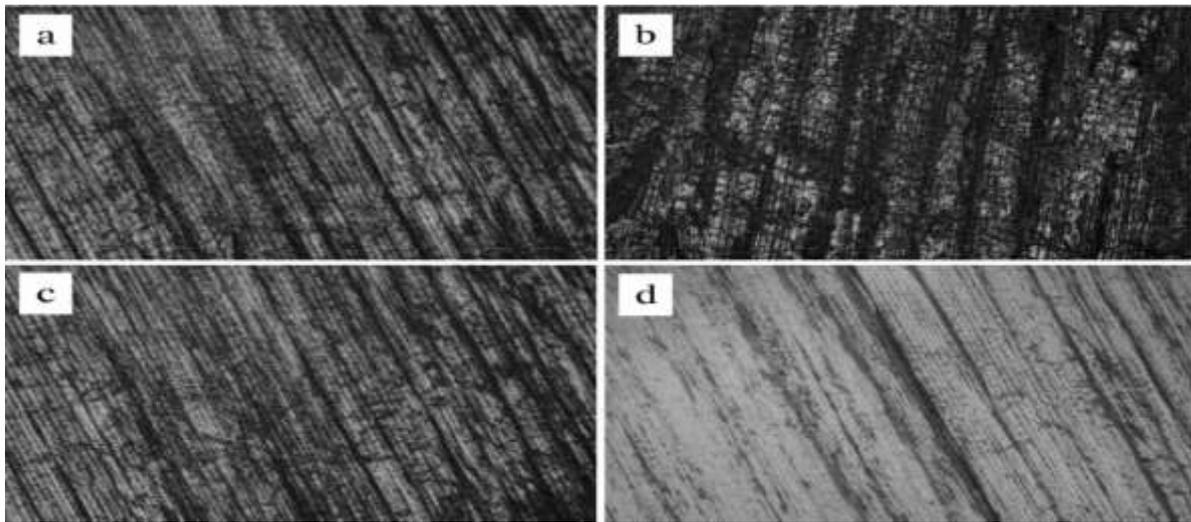
5.1.3. Effect of the sliding distance

Fig. 7 shows the effect of sliding distance versus weight loss of Al alloy and composites reinforced with 5% MoS₂, 5% Gr, and 15% B₄C particulates (Al + 5% MoS₂, Al + 5% Gr, Al + 15% B₄C), for a constant load of 30 N and sliding speed of 2.51 m/s. It can be observed from the graph that there is an improvement in wear resistance of the B₄C particulate reinforced MMC (Al + 15% B₄C), as compared to the other two MMC's and base alloy. As aluminium is soft material as compared to composites, it deforms quickly plastically. When the sliding distance increases, the weight loss also gradually increases for both reinforced and unreinforced material linearly, except for the Al-alloy containing B₄C particulates. This is because the B₄C hard particulate aspirates contact the counter disc to avoid direct metal to metal contact. During fabrication, the composite specimen induces internal residual stress; this residual stress helps to deform quickly from base material; thus, the internal residual stress accomplished with base material starts to wear out quickly. At a sliding distance above 500 m, thermal softening of matrix alloy occurs and allows direct metallic contact, which results in increased wear loss of material.

6. Surface Morphology

The worn-out surfaces of the composites at an applied load of 40 N, sliding speed of 3.76 m/s, and sliding distance of 800 m for all material combinations are depicted in Fig. 8 (a)–(d). To examine the surface morphology, pictures of the worn surfaces are extracted from the image analyzer. Since more wear loss is seen at 40 N, worn-out specimens are taken into consideration for the investigation. The Al-alloy specimen had deep grooves created by the counter surface along the rotation direction, according to micrographs. On the other hand, the flat surface of the 5% Gr composite revealed deep grooves coated in Gr particles. On the edges, there is also some layer delamination.

Fig 8.



Conclusion

The liquid stir casting method turned out to be the most effective hybrid metal matrix composite, according to the experimental investigations. The homogeneous distribution of particles in the matrix can be inferred from the surface morphology. The wear of both base and hybrid composite composites containing 5% Gr, 5% MoS₂, and 15% B₄C is mostly influenced by the applied load. The material's wear resistance is enhanced by the addition of MoS₂ and graphite reinforcement to the Al-alloy matrix. B₄C particles were strengthened in the Al-2219 matrix to increase the material's wear resistance. 15% B₄C aluminum has superior wear resistance.

7. Upcoming projects

Based on the current investigation's limited experimental results and testing, this work can be expanded to include more experimental research than optimization, and the existing method focused and produced the best outcomes. Additionally, the following significant contributions and future work can be made:

For the optimal wear property, a thorough microstructural analysis of the reinforcement and its quantity in the Al-2219 matrix can be conducted.

In order to study wear resistance on the aluminum matrix in the future, it is possible to raise the percentage of volume fraction for graphite and MoS₂ by altering the size of the reinforcement particles due to the infinite combinations of materials.

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