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STUDIES ON MICROSTRUCTURE, MECHANICAL AND TRIBOLOGICAL PROPERTIES OF 1.2MG-0.70FE-0.40CU REINFORCED WITH GRAPHITE

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ABSTRACT

Production of A6061/graphite composite with various weight fractions (5%, 10%, 15%) were prepared by using liquid metallurgy route was investigated. The preferred mean particle size of graphite is 40 µm. In addition, A6061 alloys were cast for comparison purposes. Microstructure, Mechanical and Tribological properties of these composites were evaluated and compared with as-cast alloy. The aim of present study is to evaluate the effect on the microstructure, mechanical and tribological properties of aluminum alloy A6061/graphite MMCs.

Keywords: *MMCs, Microstructure, Stir casting, Wear.*

INTRODUCTION

Composites have its wide application in defense and automotive industries because of its unique properties such as high specific strength, wear resistance, strength-to-weight, and strength-to-cost. The requirement of composite material has gaining momentum in these days due to these properties. Apart from defense and automotive industries, aircraft industries also using composites largely in the present days for reducing the weight of the aircraft and improved strength. To evident this, in modern Aircraft more than 80% of the structural materials are found made of composites. Various types of fiber based composites such as Carbon fiber; Kevlar, Glass Fiber and Metal Matrix Composites (MMC) like Aluminum and Titanium based composites were found used at present. Fiber based composites constitutes a major part as they have advantages of ease of fabrication, low cost, abundant availability etc. Though Metal Matrix Composites have the advantages of higher strength, stiffness, wear resistance and thermal resistance over fiber based composites, only few researches were noticed in exploring the applicability of MMC to aircraft manufacturing industries. In the present investigation AA 6061 alloy was chosen as matrix material because of its wider applications in the family of Aluminum-Magnesium-Silicon alloys. This alloy has a higher tensile and yield strength with lower elongation. Typical uses of this alloy are aircraft structures, rivets, hardware, truck wheels and screw machine products. At present very limited information is available on the Graphite reinforced AA 6061 alloy composites. Therefore the present investigation makes an attempt to synthesize the Graphite reinforced AA 6061 alloy composites by stir casting route; later these composites were characterized in terms of their Optical Microscope, SEM studies, hardness , mechanical and Tribological properties.

LITERATURE SURVEY

Dunand et al. [1] considered the effect of dislocation pile-ups upon the detachment threshold stress and presented a model to describe the dislocation creep mechanism for materials with high dispersoid volume fractions. The increased use of cast aluminum alloys in automotive applications such as engine blocks and cylinder heads creates the need for a deeper understanding of their mechanical behavior and the influences of processing parameters.

A comparison of the mechanical properties and the microstructure of Al 6061 alloy with Al–TiB2 metal matrix composite containing 12% by weight TiB_2p manufactured through the in-situ process were studied by T.V. Christy et al. [2]. Al 6061 alloy is widely used for commercial applications in the transportation, construction and similar engineering industries. It possesses excellent mechanical properties in addition to good corrosion

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resistance due to which the alloy finds extensive application in naval vessels manufacturing. Al-TiB_2 composite is a metal matrix composite (MMC) that can be manufactured using the in-situ salt-metal reaction. With TiB_2 as the particulate addition the properties of Al6061 alloy can be greatly improved.

Arun Kumar M B et al. [3] investigated the effect of Flyash and e glass reinforced Al6061 alloy composite having 2, 6, 8 wt. % of Flyash and 2, 6% of e glass fiber by stir casting method. Tensile test and compression test were done in universal testing machine and hardness tested on Vickers hardness tester with a load of 1N for 10 sec and micro structural analysis was done. The composite had an even distribution of reinforcements. The tensile strength of cast Al6061 alloy increased by 60% but improvement in compressive strength was marginal. Hardness increased with wt. % of Flyash as it makes more brittle. It can be seen from the literature review that the emphasis has been to replace the cast iron, which is a traditional friction material used for automobile applications by AMMCs. Among the various reinforcement materials like silicon carbide, magnesium etc., Graphite is found to be the most interesting one because of its low cost and low density. Al6061 is found to be the most useful matrix material. It is also found that the studies on the Mechanical and Wear properties of Graphite reinforced Al6061 composites are limited. Hence there is an ample scope for exploring this composite for commercial applications in the transportation, construction and similar engineering industries by taking up a study on its properties.

METHOD & MATERIAL

Al 6061 alloy is widely used for commercial applications in the transportation, construction and similar engineering industries. It possesses excellent mechanical properties in addition to good corrosion resistance due to which the alloy finds extensive application in naval vessels manufacturing. Table1.

Table 1: Chemical composition of Al6061 alloy

Si	Mg	Fe	Cu	Zn	Ti	Balance
0.40	1.2	0.70	0.40	0.25	0.15	Aluminium

Designation of Graphite Reinforced Alloy

Composites required for the present study will be prepared by Stir casting process. The composite developed by this study will contain varying percentage composition of graphite (5, 10 and 15 by weight Percentage). During fabrication of the Al6061/ graphite composite graphite of particle sizes of 40 μm were selected for the present investigation .The aim of the experiment is to study the effect of variation of the percentage composition Al6061/ graphite composite to envisage the Mechanical and Tribological properties of MMCs and Comparing the result.

Table 2: Designation of Graphite Reinforced Alloy

S/N0	Alloy/Composite	Designation
1	As-Cast (Al6061 alloy)	Ac
2	A6061+5%Graphite	5AG
3	A6061+10%Graphite	10AG
4	A6061+15%Graphite	15AG

Fabrication of Specimens

Normally the liquid-phase fabrication method is more efficient than the solid-phase fabrication method because solid-phase processing requires a longer time. Stir-casting techniques proved to be the simplest and most commercial method of production of MMCs. In this process, the crucial thing is to create good wetting between the particulate reinforcement and the molten metal, which from the In homogeneity in reinforcement distribution in these cast composites could also be a problem as a result of interaction between suspended ceramic particles and moving solid-liquid interface during solidification. This process has major advantage that the production costs of MMCs are very low. Some papers propose a two-step stir-casting process to improve the homogeneity of the reinforcements in the composite.

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Figure 1: Stir Casting Setup

Microstructure Characterization

The specimens for microstructure analysis were prepared in the form of cylindrical pieces of 20 mm diameter, 15 mm thickness and polished to obtain mirror surface finish by proper grinding, polishing and etching.

Figure 2: Polished Specimens

Hardness Test

The hardness tests were conducted as per ASTM E10 norms using Brinell Hardness Tester, where the tests were performed at randomly selected points on the polished surface of samples by providing sufficient space between indentations and distance from the edge of specimen. The hardness tests were conducted as per ASTM E10.

Tests were performed at randomly selected points on the surface by maintaining sufficient spacing between indentations and distance from the edge of the specimen. The Brinell hardness procedure consists of imprinting a steel ball of diameter D, with load F, on the piece to be examined and measuring the diameter d of the imprint left on the surface, after the load has been removed. The Brinell hardness is a value equal to a quotient of the test load F of the imprint for the area considered to be a segment of a sphere, with the ball diameter D.

Figure 3: Indentations on Hardness Test Specimen

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Tensile Test

Tensile properties of materials will be tested in Bench Tensometer**.** Ultimate Tensile Strength and percentage Elongation are obtained by carrying out an average of 3 trails each and tabulated.

Figure 4: Tensile Test Specimen after Test

Wear Test

Wear test was carried out on Pin on Disc Ducom wear testing machine. Dry sliding Wear tests are carried out at room temperature using Pin-on-Disc apparatus for varied loads and sliding distances. The wear rates are evaluated using weight loss method by dividing the loss of weight of specimen by the sliding distance for a known sliding time. The loss of weight is measured using an Electronic balance to the accuracy of 0.0001gm. The wear rate is based on the average value of 2 test results. During test, the load is increased gradually till seizure, indicated by high temperature rise; abnormal wear and vibration in Pin-disc assembly are observed.

Figure 4: Wear Test Specimens

RESULT & DISCUSSION

Microstructure Studies

Figure 5(a), 5(b), 5(c), 5(d) shows the micro photographs of both the matrix alloy Al6061 and its composites system. The microstructure clearly indicates fairly uniform distribution of reinforcement with minimal porosity in the matrix alloy in all the cast composite systems studied. Micrographs clearly reveal minimal micro porosities in the castings. The micrographs of Al6061 with 15% Graphite composite shows good interfacial bonding between aluminium matrix and graphite particle (Fig 5(d). Further these figures reveal the homogeneity of the cast composites.

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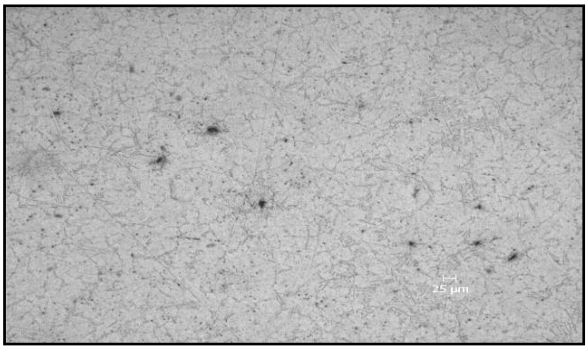

Figure 5(a): As-cast 6061

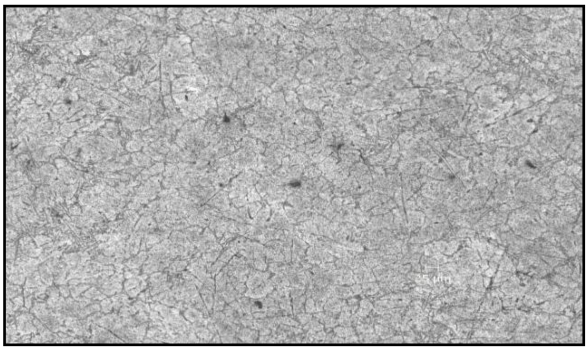

Fig 5(b) As-cast 6061+5% Gr

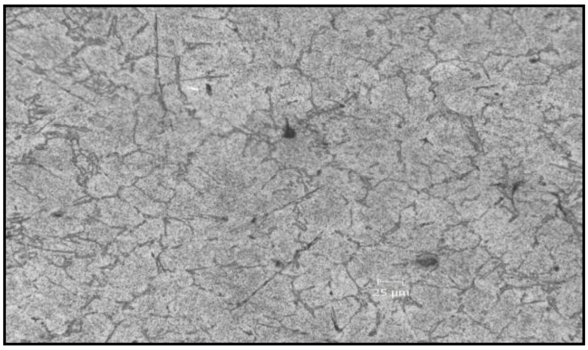

Fig 5(c) As-cast 6061+10% Gr

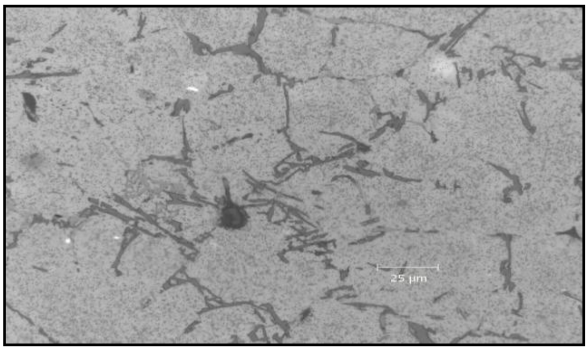

Fig 5(d) As-cast 6061+15% Gr

Figure 5: Optical Micrographs of cast Al 6061 matrix alloy and its composites.

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Scanning Electron Microscopic Studies

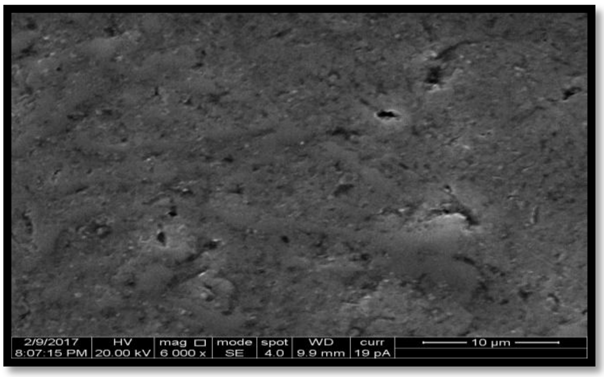

Fig 6(a): SEM Images of A6061 alloy

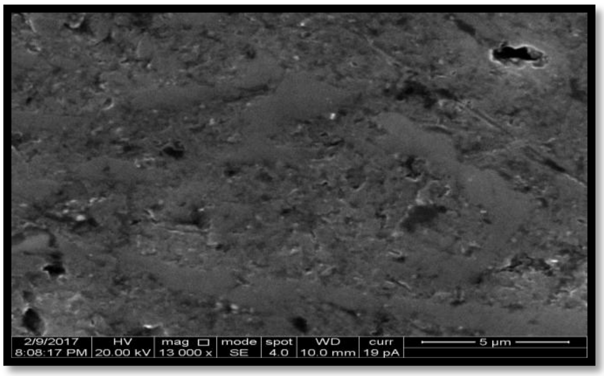

Fig 6(b) SEM Images of A6061+5% Gr

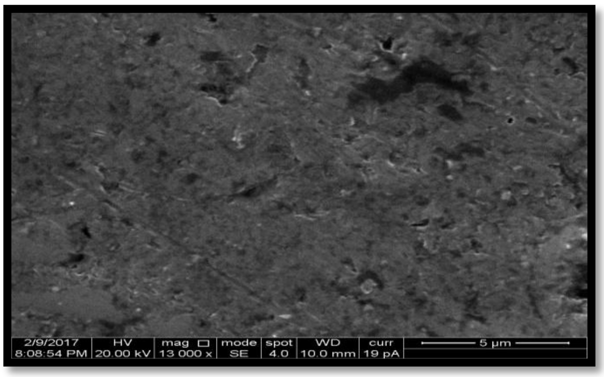

Fig 6(c) SEM Images of A6061+10% Gr

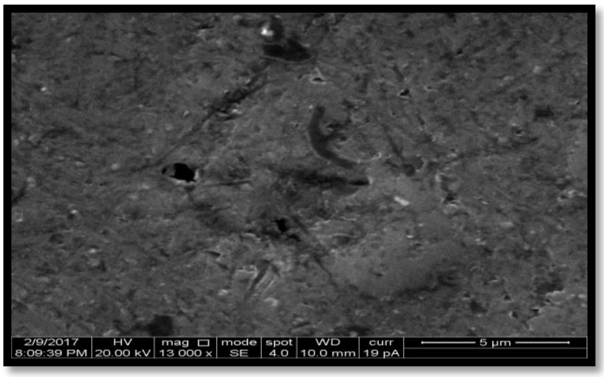

Fig 6(d) SEM Images of A6061+15% Gr
Figure 6: SEM of tensile fractured surface of cast Al 6061 matrix alloy and its composites

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Figure 6(a), 6(b), 6(c), 6(d) shows the Scanning Electron Micro photographs of both the matrix alloy Al6061 and its composites system. The SEM microstructure clearly indicates fairly uniform distribution of reinforcement with minimal porosity in the matrix alloy in all the cast composite systems studied Micrographs clearly reveal minimal micro porosities in the castings.

Hardness Test Result

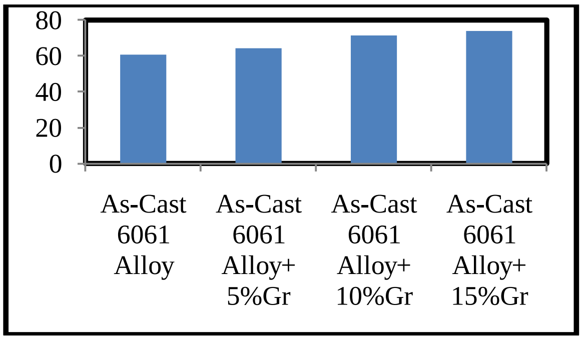

Figure 7: Hardness values of A6061 alloy and its Composites

From Figure 7 it is found that hardness increase with increasing Graphite content in the material. As compared to as-cast (AA6061 alloy), 5% Graphite addition shows an increase of 3.6 BHN (5.94%). In contrast 10% and 15% Graphite addition shows an increase of 10.8 BHN (17.82%) and 13.2 BHN (21.78%) respectively. Percentage increase in hardness was significant from 0% to 5 %,(i.e. around 5.94%) but the increase of hardness from 10% to 15% (i.e. around 3.96) was observed to be comparatively less. The improvement in hardness in casted composites may be attributed to uniform distribution of reinforcement in the matrix material

Tensile Test Result

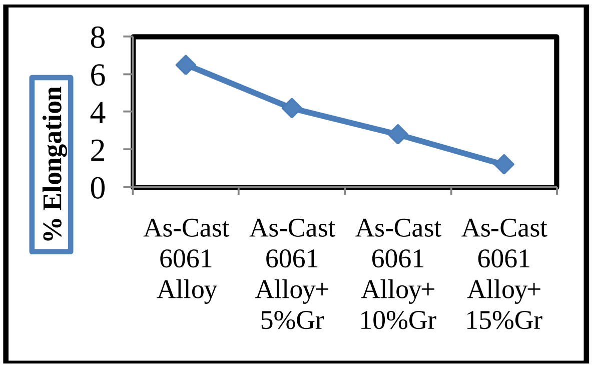

Figure 8: Variation of % Elongation with various % of Gr

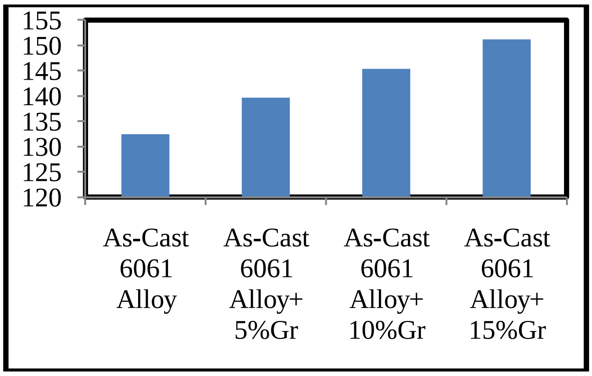

Figure 9: Variation of UTS with various % of Gr

From Figure 9 it is found that Tensile strength increase with increasing Graphite content in the material. As compared to as-cast (AA6061 alloy), 5% Graphite addition shows an increase of 7.2 MPa (5.43%). In contrast 10% and 15% Graphite addition shows an increase of 12.9 MPa (9.74%) and 18.8 MPa (14.19%) respectively.

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Percentage increase in hardness was significant from 0% to 5 %,(i.e. around 5.43%) but the increase of UTS from 10% to 15% (i.e. around 4.46) was observed to be comparatively less. The improvement in Strength in casted composites may be attributed to uniform distribution of reinforcement (Graphite) in the matrix material From Figure 8 it is found that percentage elongation decreases with increasing Graphite content in the material. As compared to as-cast (AA6061 alloy), 5% Graphite addition shows an decrease of 2.3 %. In contrast 10% and 15% Graphite addition shows an decrease of 3.7% and 5.3% respectively. Percentage decrease in ductility was significant from 0% to 5 % is around 2.3% but the decrease in ductility from 10% to 15% was observed to be comparatively more i.e. about 3.7% and 5.3% respectively.

Fractography Studies of cast As-cast matrix alloy and its Composites

Figure 10(a), 10(b), 10(c), 10(d) shows the Scanning Electron Micro photographs of tensile fractured surface of both the matrix alloy Al6061 and its composites system. It is evident that the base matrix alloy as well as composite with 10% Gr as shown in Figure 10(a) and 10(c) has got medium sized dimples and when compared to composite with 5%Gr and 15%Gr respectively showing mixed fracture. Fig 10(b) and 10(d) showing very larger dimples indicating ductile fracture.

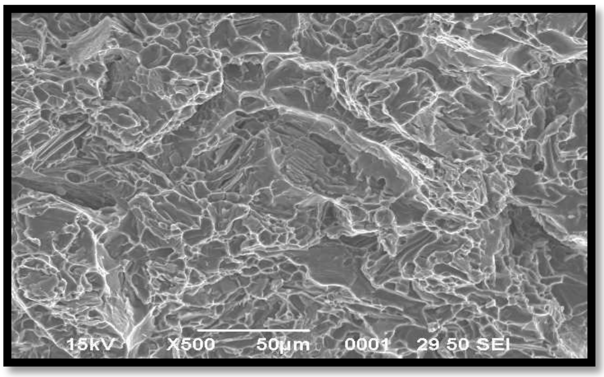

Fig 10(a): SEM Images of A6061 alloy

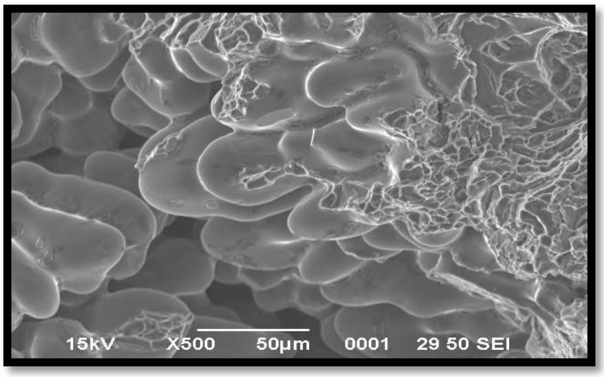

Fig 10(b) SEM Images of A6061+5% Gr

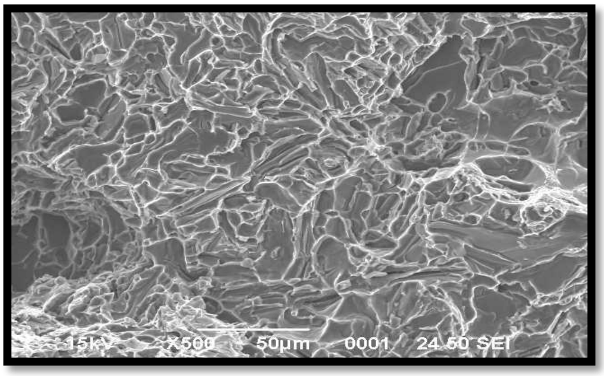

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Fig 10(c) SEM Images of A6061+10% Gr

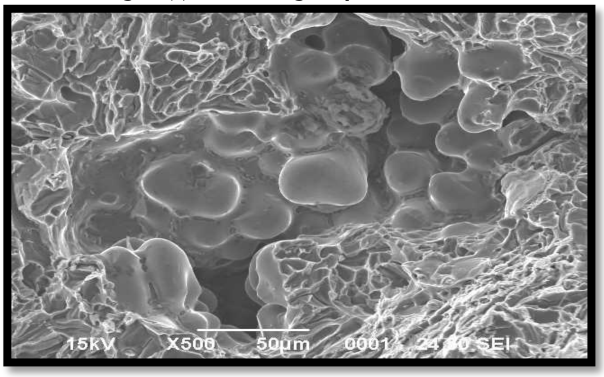

Fig 10(d) SEM Images of A6061+15% Gr

Wear Test Result

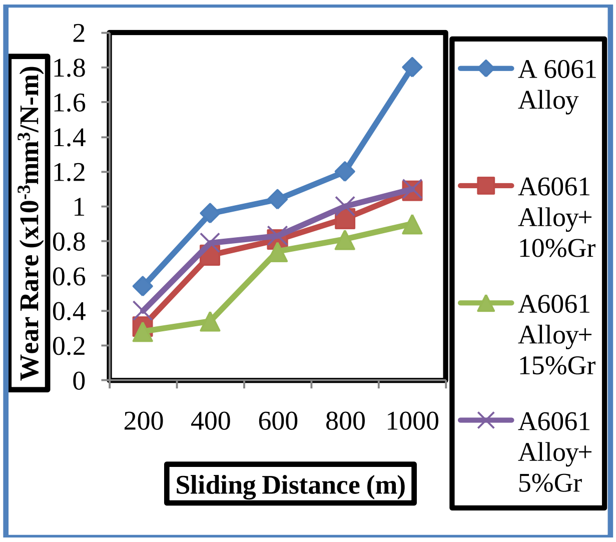

Fig 11: Wear Rate V/s Sliding Distance with % of Gr

Fig 11 shows the plot of wear rate of composite V/s Sliding distance of A6061 alloy and its composites. It can be seen from the figure that composite has a better wear resistance than the as-cast. The reduction in wear rate may be ascribed to the increase in hardness achieved due to uniform distribution and bonding of the Graphite in the composite.

CONCLUSION

In the present study, A6061/Gr composites with various weight percentages (5%, 10%, and 15%) were fabricated and studied for their mechanical and tribological properties. It was found that the wear resistance, hardness and tensile properties of composites increase with an increase of particle weight fraction and its maximum at 15%.This indicates that the optimum reinforcement for the A6061 alloy is about 15%.Wear morphology studies show that higher wear rate in case of as-cast 6061 alloy was associated with higher thickness of hardened layer and consequent delamination of wear debris from the surface. Ductile and brittle mode of fracture is observed in Fractographic observation of composite

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