Tribological Behavior of Al-6061 Metal Matrix Composites by Stir Casting Techniques

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***Abstract* - Tribological behavior of aluminum alloy Al-6061 reinforced with graphite and boron particulates fabricated by stir casting process, the reinforcing particulates in the MMC's vary from 3%, 6% and 9% by weight. The reinforcements were poured into the molten metal to produce the solid material using dies and sub-size the specimen to required shape and size. The specimens are subjected to a series of tests. And investigate the wear and frictional properties of the metal matrix composites using pin-on-disc wear tester with using the varying load, time and speed performing the experiments and finally, confirmation tests were carried out to verify the results and scanning electron microscope test were done on wear surfaces.**

Keywords: Composites, Graphite, Boron, Tribological Behavior, particulates.

I. INTRODUCTION

Aluminum is the most popular matrix for the metal matrix composites. The aluminum alloys are quite attractive due to their low density, their capability to be strengthened by precipitation, their good corrosion resistance, high thermal and electrical conductivity, and their high vibration damping capacity. They offer a large variety of mechanical properties depending on the chemical composition of the aluminum matrix.

Metal matrix composites are increasingly attractive materials for advanced aerospace applications because their properties can be addition of reinforcements. In particular, particulate reinforced MMC's have recently found special interest because of their specific strength and stiffness at relevant temperature and also strongly influenced by micro structural parameters of the reinforcement such as size, shape, orientation and volume fraction. A composite material is a combination or more chemically different materials with a distinct interface between them. It is the superiority of properties that has triggered the penetration of composite materials into all fields of manufacturing. Metal Matrix Composites (MMCs) have emerged as a class of materials suitable for structural, aerospace, automotive, electronic, Thermal and wear applications owing to their advantages over the conventional monoliths. They score over in terms of specific modulus, specific strength, high temperature stability, controlled coefficient of thermal expansion, wear resistance, chemical inertness, etc. But the down side is populated by inferior toughness and high cost of fabrication in comparison with Polymer Matrix Composites (PMCs). But MMC's supersede in terms of higher transverse strength and stiffness, shear strength and high temperature capabilities.

In recent years, considerable good work has been done on graphite reinforcements metal matrix composites which exhibit low friction, low wear rate and excellent ant seizing properties and also boron reinforcements which exhibits good hardness and provide excellent mechanical characteristics as well as high electrical and thermal conductivity properties such as tensile strength, compression strength and modulus of elasticity increases and percentage of elongation are decreases.

In the present investigation, aluminum alloy AL6061 was used as the matrix material. AL6061 alloy has the highest strength and ductility of the aluminum alloys with excellent machinability and good bearing and wear properties. Most of the particulate reinforced metal matrix composites are produced by liquid metallurgy, known as 'stir casting method' of produced aluminum metal matrix composites, in which graphite and boron particulates are used range from 50 to 200 µm are added to melting casting process since, formed the composites material to conduct the mechanical properties of tensile strength, compressive strength, young's modulus and hardness of the composite material, the present investigation aims at studying these properties in MMC's material.

II. PREPARATION OF COMPOSITES

In the present investigation, the materials tested were MMC's based on aluminum alloy 6061and graphite, boron particulates of size 50 to 200 µm, metal matrix composites were prepared by the liquid metallurgical technique called stir casting method and particulates are varying the wt % of aluminum 3%, 6% and 9%. Aluminum and aluminum alloys melts are purified by removing gaseous impurities and solid particulate impurities, primary aluminum oxides, using chemical reaction oxidation powder to remove the impurities, particulates are impregnated to molten metal at 800ºC and stirred continuously by using mechanical stirrer,

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and the stirring time was maintained at 5-7 min at a speed of manually. After complete mixing of particulate with Al alloy which is inside the crucible the molten mixture is taken outside the furnace and poured into die as.

The casting process using the metal die (Fig 1) with the standard specification of containing runner and raiser as shown in Fig. 1. While the molten metal mixture of Al & particulate is poured into die after some min its get solidified, and remove the cast product carefully.

Fig. 1 Die used to casting process and solidification

A. Machining process

After casting process is completed, preparing the specimens as per the ASTM dimensions so, the Tensile and compression specimens are not able to machine the using the simple machining process such as lathe machine, Milling because we can't achieve the accurate dimensions so, instead of that using the EDM wire cutting process to obtain the precision and accurate dimensions results.

Fig. 2 Wear test specimens

III. PREPARATION OF SPECIMENS FOR TESTING

A. Microstructure test specimen

The stages of preparation of specimens are as follows

a. Finishing the surface to be Analyzed using the emery sheets

Use different grades to rub the surface of specimen with different directions finally its gets to mirror surface.

b. Polishing the specimen

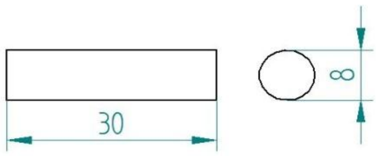
The specimens were polished on a buffing machine. The polishing material was surfaced with soft cloth. To avoid friction marks, cool distilled water was added intermittently and with addition of alumina paste and diamond polish. It was finally lapped on a soft cloth.

c. Etching

After the completion of buffing operation, the surface of the specimen was rubbed with cotton dipped in HCL which is an etchant. After etching, the surface of the specimens was washed with clean distilled water. The specimens were dried.

B. Wear test specimen

The wear test specimens are 10mm in diameter and 35mm in length from which wear test specimens are machined with 8mm diameter and 30mm length with the ASTM G95 as shown in Fig 3, initial tests are carried out in order to ascertain the range of parameters via load, speed and distance. The tribological responses are expected in terms of wear friction co-efficient and specific wear rate.



All dimensions are in mm

Fig. 3 Specimen dimension for wear test as per ASTM G95 standard

IV. RESULT AND DISCUSSION

A. Micro Structural Study

a. Scanning electron microscope

The etched specimens observed under the microscope revealed the following structure, by using SEM (Scanning Electron Microscope.

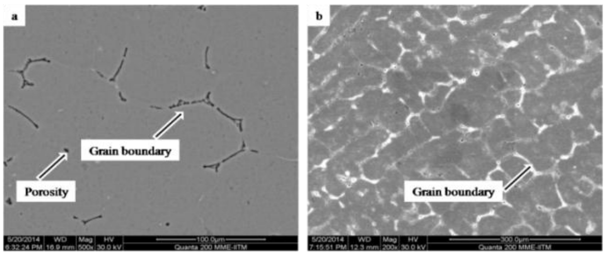


Fig. 4 SEM micrographs of MMC's Composition A (3% Gr+3% Boron)

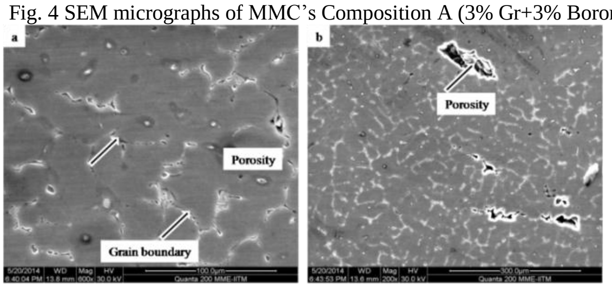


Fig. 5 SEM micrographs of MMC's Composition B (6% Gr+6% Boron)

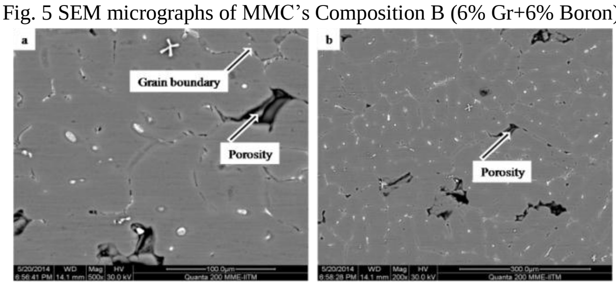


Fig. 6 SEM Micrographs of MMC's Composition C (9%Gr+9% Boron)

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The scanning electron micrographs Figure 4, 5 and 6 shows the composition A, B and C respectively. The microstructures of the composites shown differ only in the degree of reinforcing particulates with the presence of porosity and clustering.

The reinforcement particles are spherical and rectangular in shape and distributed quite uniformly in all samples. Some local clusters still can be found in all samples, especially in lower vol. % samples, the percentage of addition reinforcements are increased the mechanical defects are decreases.

B. Wear Test

Wear test are conducted on pin on disc apparatus which confirms to ASTM test standard. The disc made of EN31 steel with heat treated and Ra of 0.1 load of 0-200N can be applied with a disc speed of 200-2200 rpm. Wear along the length of the specimen to accuracy of one micron can be measured.

Consider three parameters to find the wear rate and frictional force they are listed below Varying load, varying speed and varying time.

A. Varying load

Specimen	Trail	Weight loss in gm	Load in kg	Wear rate(m^2/n) * 10^{-12}	Frictional force N*10^{-5}
Composition A	1	0.018	2	5.21	7.79
	2	0.023	3	6.54	22.03
	3	0.025	4	7.816	46.77
	4	0.026	5	9.375	95.86
Composition B	1	0.015	2	3.87	5.79
	2	0.017	3	4.51	15.20
	3	0.018	4	5.684	34.02
	4	0.02	5	7.623	71.30
Composition C	1	0.008	2	2.10	3.14
	2	0.009	3	2.40	8.08
	3	0.009	4	3.20	19.16
	4	0.01	5	5.30	49.59

Table 1 Wear test under varying load condition

From the Table 1 we observe that wear rate of the composite decreases with increase in reinforcement of the material.

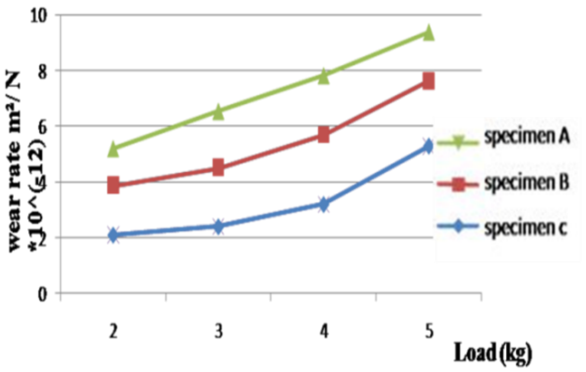

Fig. 7 Comparison of wear rate with load

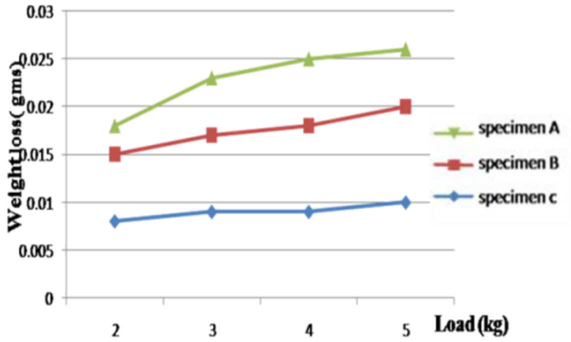

Fig. 8 Comparison of weight loss with load

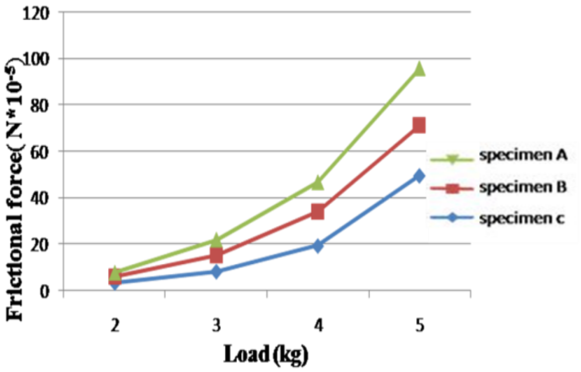

Fig. 9 Comparison of frictional force with load

Consider the wear rate of specimen A for 2kg we observe that the wear rate is 5.21*10^{-12} and for 3kg it is 6.54*10^{-12} and for 4kg it is 7.81*10^{-12} and for 5kg it is 9.37*10^{-12}.We observe that the wear rate has been continuously increased due to increase in load.

From the graphs and Table 1 we conclude that wear rate of the specimen individually like Specimen A, Specimen B, Specimen C it has been decreased with increase in addition of particulates with the same percentage.

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B. Varying speed

Specimen	Trail	Weight loss in gm	Speed in rpm	Wear rate (m^2/N) * 10^{-12}	Frictional force N*10^{-5}
Composition A	1	0.009	200	4.86	29.05
	2	0.02	400	5.68	33.96
	3	0.046	600	7.82	46.75
	4	0.083	800	10.63	63.56
Composition B	1	0.007	200	3.52	21.04
	2	0.019	400	4.70	28.10
	3	0.032	600	5.23	31.27
	4	0.058	800	7.03	42.03
Composition C	1	0.006	200	3.20	19.13
	2	0.015	400	3.98	23.79
	3	0.027	600	4.87	29.11
	4	0.04	800	5.39	32.22

Table 2 Wear test under varying speed condition

From the Table 2 we observe that wear rate of the composite decreases with increase in reinforcement of the material.

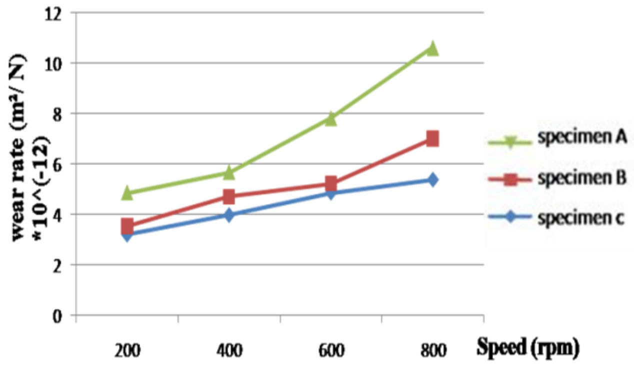

Fig. 10 Comparison of wear rate with speed

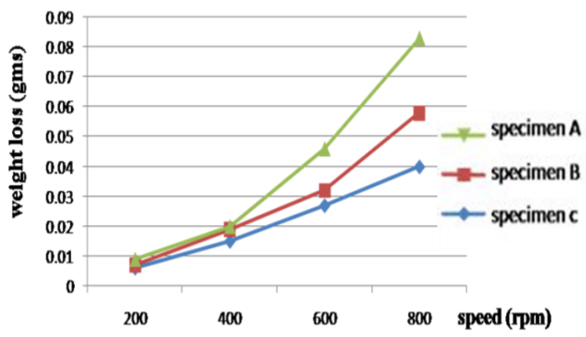

Fig. 11 Comparison of weight loss with speed

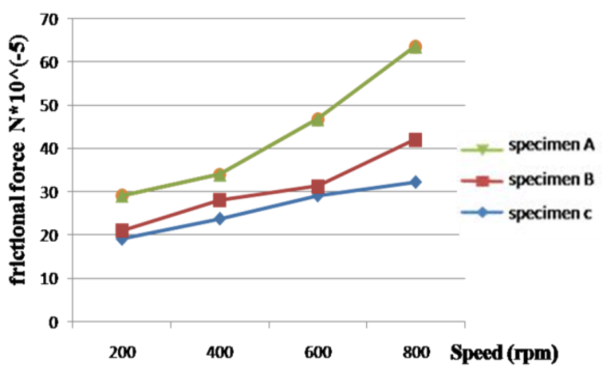

Fig. 12 Comparison of frictional force with speed

Consider the wear rate of specimen A for 200rpm; we observe that the wear rate is $4.86*10^{-12}$ and for 400rpm it is $5.68*10^{-12}$ and for 600rpm it is $7.82*10^{-12}$.We see that the wear rate has been continuously increased due to increase in speed.

From the graphs and Table 2 we observe that wear rate of the specimen individually like Specimen A, Specimen B, Specimen C it has been decreased with increase in addition of particulates with same percentage.

C. Varying time

Specimen	Trail	Weight loss in gm	Time in (min)	Wear rate (m^2/n) * 10^{-12}	Frictional force N*10^{-5}
Composition A	1	0.023	10	4.02	24.03
	2	0.046	15	5.21	31.15
	3	0.082	20	6.95	41.55
	4	0.11	25	7.82	46.75
Composition B	1	0.021	10	3.48	20.8
	2	0.043	15	4.68	27.98
	3	0.066	20	5.37	32.1
	4	0.1	25	6.70	40.06
Composition C	1	0.013	10	2.35	14.5
	2	0.022	15	2.65	15.84
	3	0.039	20	3.53	21.1
	4	0.07	25	5.3	31.69

Table 3 Wear test under varying time condition

From the Table 3 we observe that wear rate of the composite decreases with increase in reinforcement of the material.

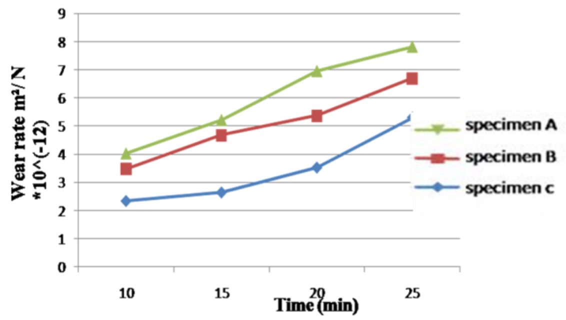

Fig. 13 Comparison of wear rate with time

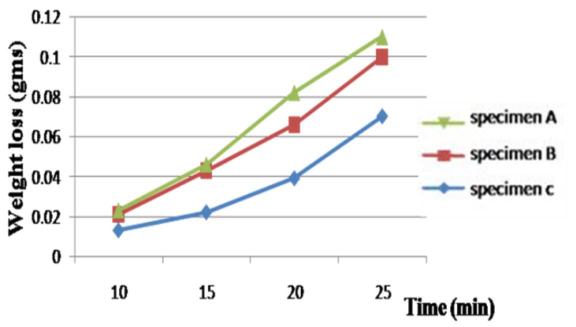

Fig. 14 Comparison of weight loss with time

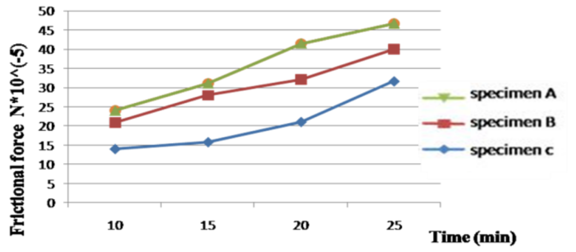

Fig. 15 Comparison of frictional force with time

Consider the wear rate of specimen A for 10min; we see that the wear rate is $4.02*10^{-12}$ and for 15min it is $5.21*10^{-12}$ and for 20min it is $6.95*10^{-12}$ and for 25 min it is $7.82*10^{-12}$. We observe that the wear rate has been continuously decreased due to increase in time.

We observe that wear rate of the specimen are like Specimen A, Specimen B, Specimen C it has been decreased with increase in addition of boron and graphite particulates with the same compositions.

V. CONCLUSION

Stir casting is effective way to obtain the samples with homogeneous microstructure and good wear properties from the obtained results the following conclusions were made.

1. The micro structural study reveals percentage of reinforcements increases in the matrix. The developed hybrid metal matrix composites shows the clear interface between the matrix and reinforcement due to good dispersion of particulates.

2. Due to the addition of reinforcements wear rate decreases for in the composition A, composition B and composition C respectively its observed with the parameters are varying load, varying speed and varying time and also decreases the frictional force.

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