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Characterization of Mechanical Properties of Aluminium Metal Matrix Composite Reinforced with Graphite Particles

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***Abstract*: Aluminum Metal Matrix Composites are used for structural, aerospace, marine and automobile applications for its light weight, high strength and low production cost. The purpose of designing metal matrix composite is to add the desirable attributes of metals and ceramics to the base metal. I. This study focuses on the effect of graphite particles addition on the mechanical properties of AA6061 metal matrix Composite manufactured by conventional stir casting process. The reinforcement content was varied from 0% to 9% in a step of 3%. The cylindrical specimens are evaluated for testing mechanical properties like tensile strength, hardness and wear test. The hardness of the composites was measured by Vickers micro hardness tester. Wear test was performed on pin-on-disc apparatus. The varying effect of graphite on properties like hardness, tensile strength and wear test is studied.**

***Keywords*: Composite, AA6061, Reinforcement, Graphite, Stirring, Hardness, Tensile Strength and Wear.**

1. Introduction

Composite materials have been the dominant engineering materials in many industries over the last decade. A Metal Matrix Composite is composite material with at least two constituent parts, one being a metal and the other may be a different material such as ceramic or organic compound. Metal Matrix Composites possess some significant properties such as high specific strength, specific modulus, damping capacity and good wear resistance. The motive behind the use of Metal Matrix Composite components in the automotive, agriculture and mining sectors is based on requirements for weight reduction and in pursuit of high efficiency and performance in the material. Hence MMC's are widely used. Aluminum alloys possess a number of characteristics that make them attractive for automotive applications: low density, good resistance to corrosion, low thermal expansion and good casting techniques for mass production. Selection of the reinforcement plays an important role in the manufacturing of MMC's. It should be stable in the given working temperature and non- reactive too. Advance technologies in MMC's provide us an opportunity to design light-weight aluminum based materials with precise balances of mechanical and physical properties. In this literature the main emphasis has been given on the wear and mechanical properties of AMC's reinforced with graphite particles. No research have been carried out in manufacturing AA6061Gr reinforced composites by stir casting process. Stir casting is one of the low cost process of all the manufacturing techniques for AMC's.

2. Experimental details

A. Procedure of stir casting

Here in this Aluminum 6061 is taken as main metal and Graphite as reinforcement.

The stir casting has been done in an open furnace where the AA6061 was melt and Graphite powder has been added. A batch of 6000 g of aluminum alloy was measured and put in the graphite crucible and was melted at 9000C using an electric furnace. The Graphite ceramic powder was preheated to a temperature of 5000C for 30 minutes prior to introduction in the melt, so that their surface gets oxidized. Argon gas was supplied to the melt this preheated graphite powder was added at a constant feed rate into vortex and stirring was done at 500 RPM for 5-7 minutes. The mechanical stirring is used to disperse the graphite particles in the matrix alloy. Coolant has been supplied so that the temperature of the melt does not exceed the maximum limit and also to stop the chemical reactions between the substances. The stirring is continued before the composite is not reached in mushy zone. The molten mixture was poured into a mound of dimension 20mm diameter and 120mm length cylindrical die. The manufactured composite was allowed to solidify in atmospheric air and was taken out from the mound after solidification. The AMCs having different weight percentage (3, 6, 9 wt. %) of Gr ceramic

Table 1
Chemical composition of base metal AA6061

constituent	Al	Si	Mg	Cu	Mn	Cr	Fe	Zn	Ti
Content (wt %)	95.85	0.8	1.2	0.4	0.15	0.35	0.7	0.25	0.15

powder were manufactured by the same procedure.

Fig. 1. Dimensions of the specimens 20 mm diameter 120 mm length

3. Testing of the MMC Specimens

A. *Tensile test*

The test was carried out on Universal Testing Machine. The main objective is to determine the tensile strength.

Fig. 2. Universal Testing Machine

The test was carried according to ASTM B557 specifications.

1) Tensile test procedure

Fix the specimen to the machine by pushing the top grip upwards and inserting the specimen into the bottom grip. Apply the load slowly. Record the reading of the load cell and the stroke. Remove the specimen from the grips and join back the broken halves together and measure the final gauge length and the diameter of the broken section. The ultimate tensile strength was evaluated on computerized universal testing machine.

Table 2
Tensile test values

Sample	Tensile test values
3% reinforcement	59.22 Mpa
6% reinforcement	38.62 Mpa
9% reinforcement	19.43 Mpa

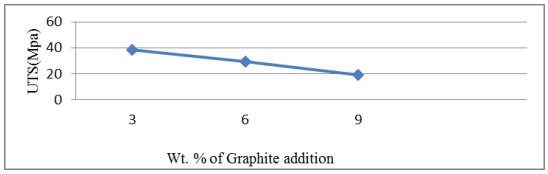

Fig. 3. Graph showing wt. % of graphite vs. UTS

By observing tensile test results, the ultimate tensile strength values are reducing by increasing the reinforcement. The Ultimate Tensile Strength (UTS) decreased from 59.22 Mpa to 19.43 Mpa with a linear increase in graphite content in AA6061.

2) Hardness test

The main objective of this test is to find the hardness of the samples at different reinforcements.

Fig. 4. Vickers micro hardness tester

Procedure:

Place the sample on the table of the testing machine. Adjust the surface of the profile projector of Vickers hardness tester. Place the cross section of the sample perpendicular to the tool traverse direction. Apply the load of 500 grams for a time period of 10 sec to obtain the hardness profile across the different regions. The dial indicator shows the readings of the specimen, readings are taken at three different locations so that exact readings.

Table 3
Hardness of the samples at different reinforcemnts

Sample ID	Hardness Values
3% Graphite reinforcement	63.4,59.4,68.7 **Avg. 65.7 HV**
6% Graphite reinforcement	63.8,51.6,54.0 **Avg. 56.4 HV**
9% Graphite reinforcement	56.2,52.5,50.1 **Avg. 52.9 HV**

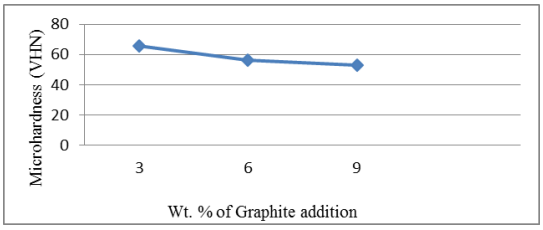

Fig. 5. Graph showing wt. % of Graphite vs. Micro-Hardness

The hardness values are reducing by increasing the reinforcement. The graph shoes that there is a decrease in the hardness values and the decrease in hardness is more from 3% to 6% reinforcement. This is because due to the addition of graphite which acts as a lubricant. The hardness of the composite decreased from 65.7 VHN to 52.9 VHN.

3) Wear test

Wear is the process of removal of material from one or both of the two solid surfaces in solid state contact. It is a surface removal phenomenon and occurs mostly at outer surfaces. It is more appropriate and economical to make surface modification of existing alloys than using the wear resistant alloys.

Table 4
Wear values (Time was taken as 5 minutes for all values)

% Reinforcement	Load	Speed (Constant)	Wear Rate (mm^3/N-m)	Coefficient of Friction (μ)
3%	20N	800	0.15	0.607
	30N	800	0.13	0.588
	40N	800	0.10	0.455
6%	20N	800	0.08	0.28
	30N	800	0.06	0.33
	40N	800	0.05	0.35
9%	20N	800	0.005	0.079
	30N	800	0.003	0.007
	40N	800	0.002	0.006

Procedure:

Dry sliding wear tests for different number of specimens was conducted by using a pin-on-disc apparatus. Parameters taken constant: pin material AA6061 + Graphite MMC, Disc material – EN31 Steel, Pin dimension- cylinder 12mm dia, height 30 mm, wear track dia- 120 mm.

Fig. 6. Pin-on-disc apparatus

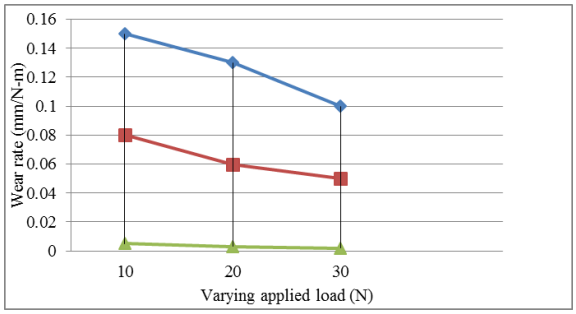

Fig. 7. Varying load vs. wear rate

Wear tests were carried out by taking the following into consideration. The surface of the pin samples were cleaned by using emery papers before the test in order to ensure fresh and flat surface with the steel disc. The samples and the wear track were cleaned before and after each test. The wear rate was calculated from height loss technique. Wear test is carried at room temperatures 30^0C. A computerized data acquisition system is used to monitor the loss in height. The sample is mounted on the pin holder of the tribometer and is ready for wear test. For the 3% reinforcement, the wear rate was calculated by taking three different loads into consideration say 20N, 30N, and 40N. And for each sample the time taken into account is 5 minutes. Speed was taken constant during the entire operation i.e. 800 RPM. After setting all the values then the operation is carried out resulting in the wear of the pin. The computerized system gives the respective wear rate and coefficient of friction values for each load. Before changing the loads surface of the pin is cleaned with the emery papers for fine wear removal. Similarly the wear rate and the coefficient of friction values are calculated for 6% reinforcements at 3 different loads by keeping the speed and the time interval constant for each load. Same procedure is repeated for 9% reinforcements and the values are taken.

Wears was calculated in terms of loss of height.

B. Results

Wear rate decreases with increase in applied load and this behavior is due to pull out of graphite reinforcement particles from AA6061 metal matrix. The decrease in wear rate may be due to addition of Graphite reinforcement particles which acts as a lubricant. It was also observed that the coefficient of friction values are also reducing with increase in reinforcements.

4. Conclusion

Fabrication of Aluminum- Graphite MMC was carried out and the following are the conclusions drawn

- By observing tensile test results, the tensile strength values are reducing by increasing the reinforcement. The tensile strength is decreasing by about 20% for 6% reinforcement and by 39% for 9% reinforcement when compared with 3% reinforcement. The Tensile strength values are highest at lower wt%. of graphite i.e. 3w.t.%.
- By observing the hardness values it was inferred that as the reinforcement increases the hardness values decreased. The main reason was due to the addition of graphite which act as a lubricant.
- Hardness, tensile strength decreased with increasing volume fraction of graphite as compared to cast AA6061 alloy.
- Wear rate reduces with increase in graphite content. Wear rate decreases with increase in applied load. Coefficient of friction also reduced with graphite addition.
- It was observed that by the addition of the reinforcement, all the values were reducing. By this it was concluded that the graphite reduces the wear

phenomenon, and this MMC is used in situations where high wear occurs.

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