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THREE-BODY ABRASIVE WEAR BEHAVIOR OF ALUMINIUM ALLOY REINFORCED WITH GRAPHITE PARTICULATES

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Abstract

Aluminium matrix composites are being used in many areas like automobiles aerospace and marine industries in this work aluminium alloy is used as metal matrix and graphite is selected as reinforcement with varying weight percent from 0% to 6% with the increment of 2% to find the effect of graphite on mechanical and tribological properties. Composite was prepared by using stir casting method. The majority of work has been carried out on aluminium metal matrix composite but less work has been done on three body abrasive wear. Micrographs will ensures the presence of graphite particulates in the prepared composite. The specimen subjected to mechanical properties and wear behavior the result shows that the reinforcement of the particles enhance the mechanical property as well as wear property with increase in weight percentage of reinforcement. The results are tabulated and graph is plotted to analyze the improvement upon addition of graphite particulate and surface studied were done through SEM and optical microscope.

Key words: Aluminium 6061, Graphite, wear test, Hardness test

1. Introduction

A composite material is a material made from two or more constituent materials with significantly different physical and chemical properties that combined to produce a material with different characteristics from the individual components. The physical properties of composite materials are not isotropic in nature, but they are typically anisotropic Generally one component act as a matrix in which the reinforcing phase is distributed. The matrix component is, thus the continuous phase when the matrix component is metal we call such composite is metal matrix composite(MMCs). The reinforcement can be in the form of particulate, viscous, short fiber or continuous fibers in this study we had been taken particulate reinforcement size of 100 µm. composite materials are popular because of light weight, corrosion resistance low thermal conductivity, high strength, design flexibility and durability. Most composites are created to combination of mechanical and tribological properties many composite and also to obtain high temperature strength. Many composite material are composed of just two phases one phase the matrix which is continuous and surrounds the other phase called reinforcement. The properties of the composite depend upon the types of reinforcement, their amount and the geometry of reinforcement and their orientation.

1.1 Aluminum Metal Matrix Composites

Aluminum is the most widely used metal in the world apart from iron, because of its unique combination of properties, such as low weight, corrosion resistance, and easy maintenance of final product, and also high strength to weight ratio, low cost and high wear resistance. It is mostly used in structural applications along with aerospace and automobile industry. The present work focuses on metal matrix composites and more specifically on the Aluminum Metal Matrix Composites (AMMCs). In AMMCs, the major constituent is aluminum alloy, which forms percolating network and acts as the matrix phase. The other constituent added in the aluminum alloy matrix and serves as reinforcement are usually non-metallic, and commonly include ceramics such as silicon carbide and aluminum oxide.

1.2 Graphite

Graphite archaically referred to as Plumb ago, is a crystalline form of carbon, a semi metal, a native element mineral and one of the allotropes of carbon. Graphite is the most stable form of carbon under standard condition. Therefore it is used in thermo chemistry as the standard state for defining the heat of formation of carbon compounds. Graphite may be considered the highest grade of coal, just above anthracite and alternatively called meta-anthracite, although it is not normally used as fuel because it is difficult to ignite.

Graphite is a well-recognized solid lubricant which also has the advantage of low density. Graphite has physical properties of thermal and, good electrical conductivity. In graphite reinforced AMCs, graphite serves as a solid lubricating layer between the composite and rubbing surface helping in reduction of composite wear without the need for traditional solid and liquid lubrication. To change the tribological behavior reinforcement was added with alloy. Graphite Powder of 100 micron was used.

Graphite and graphite powder are valued in industrial applications for their self-lubricating and dry lubricating properties. There is a common belief that graphite’s lubricating properties are solely due to the loose inter-lamellar coupling between the sheets in the structure .Graphite powder is shown in figure 1.

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Figure 1: Graphite Powder

2. Problem definition and objectives

2.1: Problem Definition

From literature survey it is found that majority of work has been carried out on pure Aluminium, 6 series and 7 series to characterize the mechanical, tribological and machinability of composites, and less work is focused on 8 series Aluminium. Hence in this work Al 6061 alloy is used as metal matrix. The reinforcement material being used is graphite in previous works is compared with the reinforcement material red mud in current work.

In many investigation Titanium carbide, Silicon carbide, Boron carbide, Al_2O_3 are commonly used ceramic reinforcement to enhance the mechanical properties, and few researchers have used Graphite as reinforcement with limited weight percent of 5% to 20 % for the hybrid composite. Hence in this present work Graphite is selected as reinforcement with varying weight percent from 0 to 6% with the increment of 2% to find the effect of Graphite and red mud on mechanical and tribological properties.

From literature review considerable work has been carried on wear studies Pin and Disc apparatus to find the wear behavior of composite, but less work has been done on Three Body abrasive wear. In this work Al 6061 is reinforced with Graphite and no work has been yet carried out on Al 6061 reinforced with red mud to find wear behavior by using 3-Body abrasive wear test.

2.2 Objectives

The main objective of the project is to estimate the tribological performance of Aluminum - Graphite metal matrix composite and Aluminium – Red mud metal matrix composite to provide a better comparative study, here 3-body abrasive wear is employed. It is achieved through following sub objectives.

- To synthesize Aluminum -Graphite composite by using two step stir casting method.
- Aluminum – Red Mud composite by using two step stir casting method.
- To analyze micro structure to ensure uniform distribution of reinforcement.
- To analyze the effect of parameters namely; Graphite weight %, load, time and to relate their influence on mechanical & tribological behavior using 3-body abrasive wear.

3. Experimental details

To achieve the main objectives of the project, the experimental work is planned in the following sequence.1) Calculation of different proportions of composite 2) Composite Preparation and 3) 3-body abrasive wear test and Hardness test.

3.1 Calculation of Different Proportions of Composite:

The following calculation gives the quantity of Aluminum, Graphite, Redmudand Magnesium to be used for preparing the specimen for testing.

Base Metal Calculation:

Mass of each rectangular specimen, $M = \rho \times V$
Where $V = l \times b \times h\ cm^3$ =Volume of mould box.
$= 150 \times 0.8 \times 2.5$
$V = 30 cm^3$
ρ is density of Aluminum=$2.72 gm/cm^3$
Therefore $M = 30 \times 2.72$
$M = 81 gm$
14% Shrinkage +10% Slag =24%
$= \frac{81X24}{100}$
=19.44gm
Total weight of Aluminum required per specimen=81+19.44=100.44 gm.
Considering allowance for wastage while pouring, approximately 110gm of aluminum was taken for each specimen. For 5 specimens =110×5=550gm.
All the specimens are cut to required dimensions of 75mm x 25mm x 8mm as per ASTM G-65 standard.

Reinforcement Calculation:
Graphite was added from 0% to 6% with increment of 2% with respect to aluminum weight, the calculations are as follows.

1) Base metal= 990
=990gm (No addition of graphite)
2) 2% of graphite = 990x2 /100 = 19.8gm
3) 4% of graphite =990x4 / 100 = 39.6 gm
4) 6% of graphite =990x6/100 = 59.4 gm

3.2 Composite Preparation
In view of increasing commercial interest in the production of composites, and challenge has been made to study the effect of process parameters such as graphite weight percentage, load, time on the distribution of reinforcement particles in molten Aluminum-Graphite which are fabricated by two stage stir casting method.

In this work, Al 6061 was selected as base metal and Graphite powder of 100 micron was used as reinforcement. Table1 and Table 2 shows physical and chemical properties of Al 6061 base metal, and Table 3 shows physical and mechanical properties of Graphite.

Table1: Physical Properties of Al-6061

Density	Ultimate Tensile Strength	Elastic Modulus	Strength to Weight Ratio	Thermal Expansion
2.72 g/cm3	110Mpa	71GPa	40kN-m/kg	21.8µm/m-k

Table 2: Chemical Composition of Al-6061

Material	Fe	Si	Mn	Zn	Cu	Ti	Cr	Mg	Al
Weight%	1	0.9	0.2	0.1	0.1	0.08	0.05	0.05	97.5

Table 3: Material Properties of Graphite

Property	**Commercial graphite**
Density	1.3-1.95 g/cm^3
Porosity	0.7-53 %
Modulus of Elasticity	8-15 Gpa
Compression strength	6.9-100 Mpa
Thermal conductivity	25-470 W/m.k
Electric resistance	5×10^{-5} -30×10^{-6} Ω.m

The composite was prepared by two step stir casting method, because it gives uniform distribution of reinforcement throughout the alloy and is easy and economical. In two step stir casting process, first the Aluminum is heated to above its liquids temperature. The melt is then cooled down to a temperature between the liquid and solidus points to a semi-solid state. At this point the preheated reinforcement (i.e. Graphite powder) is added and mixed. Again the composite is heated to a fully liquid state and mixed thoroughly. The Aluminum was in the form of stripe, cut into small pieces with the help of hand press. Quantity of reinforcement was varied from 0% to 6% with increment of 2%. As shown in the calculation 550gm of Al and 4 different weight percentages of reinforcements were used to prepare 5 specimens of each composition. Cut Al ingots were placed in graphite crucible, the maximum temperature of crucible is 2000^{0}C, and then the crucible was placed in resistance furnace. Figure 3 shows resistance furnace. It was than heated up to 750 ^{0}C, its maximum temperature being 1200^{0}C. Reinforcement was preheated to a temperature of 300^{0}C in a preheated. Before mixing reinforcement in molten metal, 2Wt% of Magnesium was mixed to the molten metal to facilitate the uniform dispersion of particles into the Al during melting and also to improve the wettability between reinforcement and molten metal. To remove entrapped gases degassing tablet was added in to the molten metal. Finally the preheated reinforcement powder was poured into the molten alloy in two steps and stirred continuously by zebrine coated steel stir about 300sec and stirring was gradually increased up to 300rpm. The prepared composite molten metal was poured into already prepared permanent mild steel mould box, of dimensions 150 mm length, 8 mm thick, and 25 mm width is shown in figure 4. Before pouring, the mould box was cleaned and preheated to a temperature of 150 ^{0}C to 200 ^{0}C. Molten metal was cured for 5 to 10 seconds in mould box and cooled in air. Molded specimens are shown in figure 2.The specimens were cut according to ASTM G-65 standard, to the dimension of 75mm×8mm×25mm and are shown in figure 3. Optical Micrographs were used to check uniform distribution of Graphite in Aluminium.

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Figure 2: molded specimens

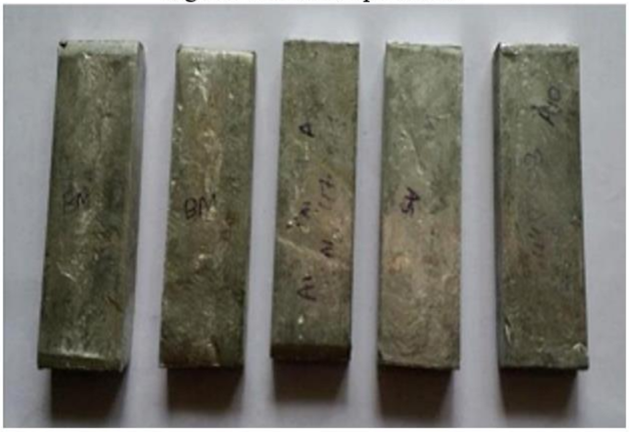

Figure 3: Specimen cut ASTM G-65 standards

4. Results and Discussion

This work presents the results of the three-body abrasive wear test conducted on Al 6061 reinforced with graphite and red mud. The influence of weight percent, load and time of wear on composite is discussed. The microstructure of composite is also discussed below.

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4.1 Microstructure

Microstructure of a material is defined as the structure of a prepared surface of material as revealed by a microscope above 20 magnification scale. The microstructure of a material can strongly influence physical properties such as strength, toughness, ductility, hardness, corrosion resistance, high/low temperature behavior or wear resistance. These properties in turn govern the application of these materials in industrial practice. When polished flat sample reveals traces of its microstructure, it is normal to capture the image using microscopy. More sophisticated microstructure examination involves higher powered instruments: optical microscopy, electron microscopy, X-ray diffraction etc, some involving preparation of the material sample (cutting, microtomy, polishing, etching, vapor-deposition etc.). The methods are known collectively as metallography as applied to metals and alloys, and can be used in modified form for any other material. Specimens of Al-6061 reinforced with graphite were etched with the Keller's reagents and cleaned for about 5-10sec before microstructure was performed. Keller's reagent consists of 95ml water, 2.5 ml HNO_3, 1.5 ml HCl, 1.0 ml HF. The microstructure of Aluminum 6061 and Graphite composite is show in figure 4 (b), (c), (d). The micrographs show that there is a uniform distribution of Graphite particles throughout the Aluminum alloy, with increasing the Graphite percentage the mixing also increased. From the micrographs it is also found that there is a good bonding between Aluminum and Graphite.

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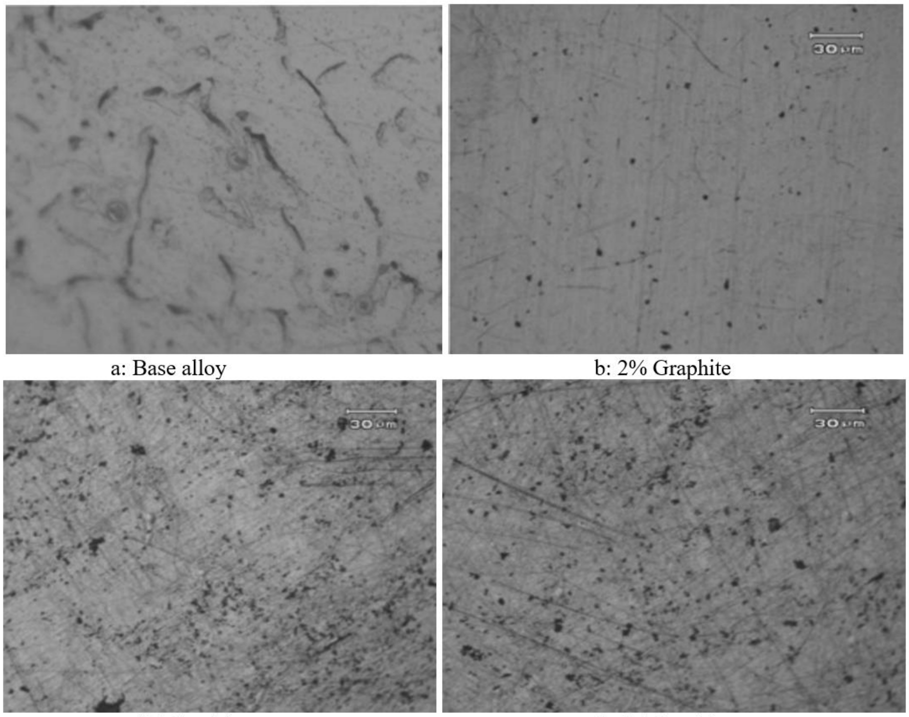

a: Base alloy b: 2% Graphite

c: 4% Graphite d: 6% Graphite

Figure 4 : Microstructure

4.2 Hardness

Hardness is defined as "Resistance of metal to plastic deformation, usually by indentation. However, the term may also refer to stiffness or temper, or to resistance to scratching, abrasion, or cutting. It is the property of a metal, which gives it the ability to resist being permanently, deformed (bent, broken, or have its shape changed), when a load is applied. The greater the hardness of the metal, the greater resistance it has to deformation.

The Hardness of prepared composites was measured by Brinell Hardness Tester. Brinell hardness is determined by forcing a hard steel or carbide sphere of a specified diameter under a specified load into the surface of a material and measuring the diameter of the indentation left after the test. The Brinell hardness number, or simply the Brinell number, is obtained by dividing the load used, in kilograms, by the actual surface area of the indentation, in square millimetres. The result is a pressure measurement.

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Figure 5: Specimen before Hardness Test

Figure 6: Specimen after Hardness Test

Table 4: Hardness values of base alloy and composites

SL NO	Composition Material	VHN
1	Base alloy	52
2	Al-2%Grp	56
3	Al-4% Grp	64
4	Al-6% Grp	72

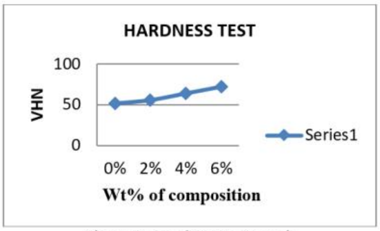

Figure 7: Hardness test graph

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The hardness of the matrix and composite were evaluated at 4 different locations of the prepared specimens using Brinell hardness tester and average of 4 readings are plotted in Figure 7. From the results obtained it was observed that with the increases in weight percentage of Grp the hardness value of the composite increases and addition of Grp to the base alloy also increases the hardness dependently.

4.3 Wear Test

The aim of wear test is to determine the significant factors, relation between them and their optimum values to achieve the minimum wear rate. It is observed from the values given in Table 5 that composite without graphite shows greater wear, in comparison to the composite with graphite. May be this is because graphite particles act as a solid lubricating layer between composite and rubbing surface. The wear rate decreases as the percentage of graphite increases from 0 % to 6%. Specimen before and after wear test is shown in figure 8 and figure 9.

Figure 8: Specimen Before Wear Test

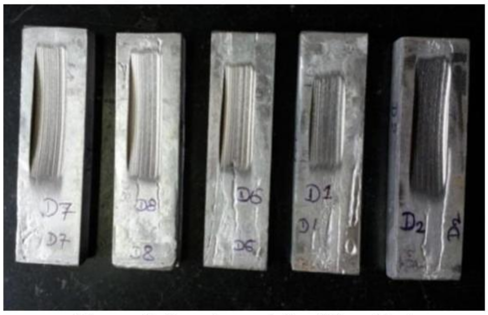

Figure 9: Specimen After Wear Test

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CALCULATIONS:

Wear rate= $\frac{m}{(\rho * t * V_s * F_N)}$ mm^3/Nm

Trial I :

Where m = 0.98 g

ρ = $2.7*10^3$ kg/m^3

t = 10 min v = 200 rpm Fn = 98.1 N

Wear rate = $\frac{0.98}{2.7*10^3*10*200*98.1}$

= $1.85*10^{-9}$ m^3/Nm

Wear rate = 1.85 mm^3/Nm

Trial II :

Where m = 5.63 g

ρ = $2.7*10^3$ kg/m^3

t = 20 min v = 200 rpm Fn = 196.2 N

Wear rate = $\frac{0.98}{2.7*10^3*10*200*98.1}$

= $2.65*10^{-9}$ m^3/Nm

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Wear rate = 2.66 mm^3/Nm

Table 5: Wear Rate of Al-Grp Composites:

Sl No	Wt %	Time(min)	Load(Kg)	Wear rate in mm^3/Nm
1	0	10	10	1.85
2	0	20	20	2.66
3	0	30	30	3.04
4	2	10	10	1.79
5	2	20	20	2.57
6	2	30	30	2.85
7	4	10	10	1.52
8	4	20	20	2.23
9	4	30	30	2.70
10	6	10	10	0.78
11	6	20	20	1.79
12	6	30	30	2.11

From the obtained results it is cleared that the presence of reinforcement in the alloy will affect the wear behavior of the composite result of this wear test of Al-Grp composites are shown in Table no 5. The graphs are plotted against the applied load and wear rate by keeping time constant. These graphs reveal that the wear resistance of composite increases when reinforcement content is increased from 2% to 6%.

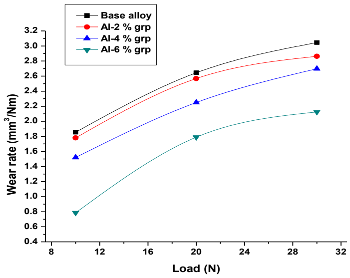

Fig 10 : Wear rate of composite Al-Grp composites

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5 Conclusions

Aluminium Metal Matrix Composites have been in extensive demand due to their promising properties with respect to space, aerospace and automobile applications. In the present research work aluminium-graphite particulates (Al-Grp) reinforced composites were synthesized by traditional stir casting route. The wear tests were carried out by using 3-body abrasive wear test with varying load from 10-30kg and time from 10-30min.The major conclusions are drawn as follow.

- Two step stir casting method can be satisfactorily used to fabricate Al-Grp composites. Micrographs show fairly uniform distribution of Graphite and Red mud with Al 6061metal matrix composite.
- Both red mud and graphite can be successfully used in the place of conventional aluminium intensive materials, and also saving the usage of about 10 percent of matrix material could be achieved.
- Increasing the concentrations of Graphite (from 0% to 6%), increases the mechanical properties, hardness and wear resistance of the composites.

References

[1] M. Sankar, A. Gnanavelbabu, K. Rajkumar “effect of reinforcement particles on the abrasive assisted electrochemical machining of Aluminium-Boron carbide-Graphite composite” **97,** 2014

[2] K Rajkumar, S Santosh,SJaved Syed Ibrahimc, A Gnanavelbabu “Effect of electrical discharge machining parameters on microwave heat treated Aluminium-Boron carbide-Graphite composites”, **97**, 2014

[3] K. R. Padmavathi ,Tribologicalbehaviour of aluminum hybrid metal matrix composite, **97**, 2014

[4] Kenneth KanayoAlaneme, KazeemOladitiSanusi “Microstructural characteristics, mechanical and wear behavior of aluminium matrix hybrid composites reinforced with alumina, rice husk ash and graphite” **18**, 2015

[5] M. Sankar, A. Gnanavelbabu, K. Rajkumar “effect of reinforcement particles on the abrasive assisted electrochemical machining of Aluminium-Boron carbide-Graphite composite” **97,** 2014

[6] HimanshuKala,K. K.S Mer, Sandeep Kumar “A review on mechanical and tribological behaviors of stir cast aluminum matrix composites.”**6**, 2014

[7] N. Radhika, R. Subramania, S. VenkatPrasat,TribologicalBehaviour of Aluminium/Alumina/Graphite Hybrid Metal Matrix Composite Using Taguchi’s Techniques, **10**,2011