Evaluation of Mechanical Properties of Al-Cu Alloy with Graphite and Fly Ash Composite Material

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***Abstract*— Metal matrix composites (MMCs) are engineered materials, formed by the combination of two or more dissimilar materials (at least one of which is a metal) to obtain enhanced properties. In the present investigation, an Al–4.5% Cu alloy was used as the matrix and fly ash as the filler material, graphite is reinforcement. In the present, aerospace, automobile industries, replacing the existing metal matrix composites from Al 6061 to its high performance application. Aluminum copper alloy matrix composite attracts the much attention due to their lightness, high thermal conductivity, moderate casting temperature etc. Fly ash and graphite powders are used because of its High strength, High hardness, and less density. The composite was produced using stir casting method. The fly ash was added in 3%, 6%, and 9 wt. % and graphite was added in 3%, 6%, and 9 wt. % to the molten metal. The composite was tested for fluidity, hardness, density, mechanical properties. Microstructure examination was done using a scanning electron microscope to obtain the distribution of fly ash and graphite in the aluminum matrix. The results shows, an increase in hardness, tensile strength with increasing the fly ash and graphite content. The density decreases with increasing fly ash content. Corrosion increases with increasing fly ash content. Specimen is fabricated at different weight percentages and to be carried out for mechanical properties.**

Keywords*— *Aluminium, Composite, Fly ash, Graphite, Hardness, Matrix

I. INTRODUCTION

Traditional materials do not always provide the necessary properties under all service conditions. Metal matrix composites (MMCs) are advanced materials resulting from a combination of two or more materials (one of which is a metal and the other a non-metal) in which tailored properties are realized. They have received considerable attention in recent years due to their high strength, stiffness, and low density. Data related to mechanical properties, wear, microstructure, etc., have been cited in the literature. It has been reported that particle size and wear parameters (sliding speed, material property, normal load) influence the wear of the material [1–3]. A variety of particles such as mica, Al_2O_3, graphite, and Sic have been used as reinforcement materials with aluminium alloys [4–8] as the matrices. It appears that stir casting is one of the methods for producing composites. The use of fly ash as a reinforcement material [9] results in improvement of mechanical properties of the composite. An extensive review on dry sliding wear characteristics of composites based on aluminium alloy was undertaken by reference [10] and of their abrasive wear behavior by Deuis [11]. Fly ash was separated into cenosphere and precipitator fly ash. The use of precipitator fly ash in aluminium decreases the density of composites and increases their wear resistance [12]. In slurry erosive wear, the effect of the impingement angle and velocity on the erosion rate depends on particle size and amount of particulates. It has been reported that the erosion rate increases with increasing particle size up to a point, beyond which it is not significantly affected by the size. It was reported that corrosion increases with increasing particulates in composites [13].

Reference [14] reported the pitting corrosion behavior and corrosion kinetics of Al alloy with precipitator fly ash (9 vol %, 75–100 μm) composites. It was found that fly ash particles lead to an enhanced pitting corrosion of the composition comparison to unreinforced matrix. In the present investigation, Al–4.5% Cu alloy with fly ash (as received from a thermal power plant) as particulates were successfully fabricated using the stir casting method. Fluidity, mechanical properties, dry sliding wear, slurry erosive wear, and the corrosion behavior of the MMCs were investigated.

II. EXPERIMENTAL

Aluminium with 4.5% Cu was selected as the matrix material. The chemical composition, analysed by a Bairdas DV-6S optical emission spectrometer, is given in Table 1. Fly ash was used as the reinforcement and its composition is given in Table 2. The average particle size was found to be 10 μm. The density of fly ash was found to be 2.09 g/cm3. Fig. 1 shows SEM micrographs of fly ash particulates.

Table 1. Chemical composition of Al–4.5% Cu alloy

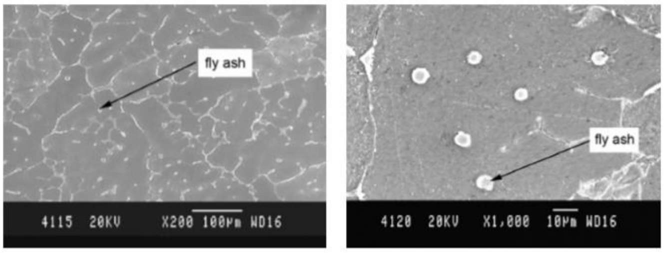
Cu	Mg	Si	Fe	Mn	Ni	Pb	Sn	Ti	Zn	Al
4.52	0.06	0.53	0.66	0.13	0.07	0.02	0.02	0.01	0.01	balance

Table 2. Chemical composition of fly ash in weight percentages

Al_2O_3	SiO_2	Fe_2O_3	TiO_2	Loss on ignition
30.40	58.41	8.44	2.75	1.43

The synthesis of the composite was carried out by stir casting. The ingots of Al–4.5% Cu alloy were taken in a graphite crucible and melted in an electric furnace. The temperature was slowly raised to 850 °C. The melt was degassed at 800 °C using a solid dry hexachloroethane (C_2Cl_6, 0.5 wt. %) degasser. The molten metal was stirred to create a vortex and the particulates were introduced. The degassed molten metal was placed below the stirrer and stirred at approximately 500 rpm. The preheated fly ash & graphite particles were slowly added into the melt. Small pieces of Mg chips (0.5 wt. %) were added to the molten metal to ensure good wet ability of particles with the molten metal. The percentage of fly ash added 3, 6, and 9 wt. % also the percentage of graphite added was 3, 6, and 9 wt. %. The stirred dispersed molten metal was poured into preheated S.G. iron moulds 25, 37,and 50 in diameter and 200 mm height, and cooled to room temperature.

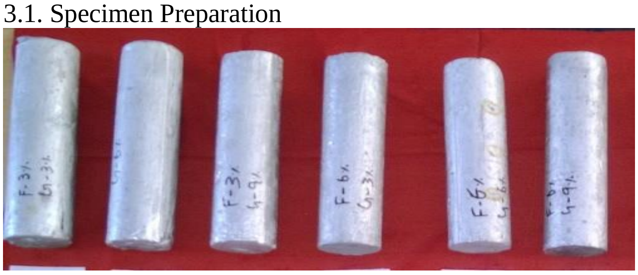
Fig. 1. SEM of fly ash particulates



Composites produced were subjected to solutionisation and age hardening (T6). The castings were heated to 525 °C and held for 17 hours, quenched in warm water, then reheated to 175 °C and held for 18 hours. They were sectioned and test samples were prepared for various tests. The density of the specimens were measured using the Archimedes principle. Their hardness was determined using the Brinnel hardness tester. The load of 250 kg using a 5 mm steel ball indenter was used to measure the hardness. The microstructure of the MMCs was observed under a scanning electron microscope (SEM) at various locations across the specimen to examine the distribution of fly ash and graphite in the matrix.
Tensile strengths is determined using a 20 kN computerized UTM with an electronic extensometer as per ASTM E-8 standards. Online plotting of load versus extension was done continuously through a data acquisition system. Dry sliding wear test. Specimens 5 mm in diameters and 20 mm long were used for the dry sliding wear tests. The tests were carried out using a computerized pin on a disc wear testing machine under ambient temperature conditions on specimens for normal loads of 4.9, 9.8, 14.7, and 19.6 N, and for a constant track velocity of 250 rpm.A hardened steel disc (60 HRc) was used as the counterface. The wear of the specimen and friction were measured directly using sensors.

III. EXPERIMENTAL PROCEDURE

3.1. Specimen Preparation



Fly ash and graphite reinforced Aluminium 4.5% alloy (Al6061) composites, processed by stir casting route was used in this work. The required quantities of fly ash and graphite are Flyash3% Graphite3%, Flyash 3% Graphite 6% Flyash 3% Graphite 9%, Fly ash 6 % Graphite 3%, Flyash 6% Graphite 6% Fly ash 6% Graphite 9% were taken in powder containers. Then the fly ash was pre heated to 450ºC and maintained at same temperature for about 20 min. then weighed quantity of Al (6061) alloy was melted in a crucible at 850ºC which is more than 100ºC above liquid temperature of the matrix alloy. The molten metal was stirred to create a vortex and the weighed quantity of preheated fly ash and graphite particles were slowly added to the molten alloy. A small amount of Mg (0.5 wt. %) was added to ensure good wet ability of particles with molten metal. After mixing the melt was poured into a prepared mould for the preparation of specimen.

Table 1 shows the chemical composition of the Al–4.5% Cu alloy

Element	Weight percentage
Copper	4.5
Chromium	0.30
Magnesium	1.00
Zinc	0.20
Iron	0.65
Manganese	0.10
Silicon	0.60
Titanium	0.10
Aluminium	remaining

3.2. Testing for Mechanical Properties

The tensile tests were conducted on these samples according to ASTM E8-95 at room temperature, using a universal testing machine (INSTRON). The specimens used were of diameter 12.5mm and Gauge length 62.5 mm, machined from the cast composites rod of 25mm diameter and 200mm long with the gauge length of the specimen parallel to the longitudinal axis of the castings. The Brinnel hardness tests were conducted in accordance with the ASTM E10.

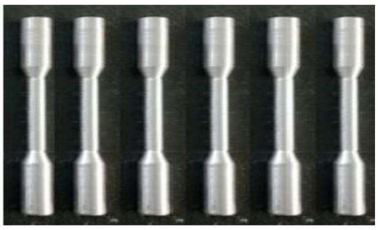
Variation of Flyash and Graphite for 37mm diameter rod				
WEIGHT OF THE ALUMINIUM WITH COPPER ALLOY	37mm diameter & 200mm long			
	Fly ash		Graphite	
	%	wt.gm	%	wt.gm
580 gms for 1 rod	3	17.4	3	17.4
	3	17.4	6	34.8
	3	17.4	9	52.2
	6	34.8	3	17.4
	6	34.8	6	34.8
	6	34.8	9	52.2
	9	52.2	3	17.4
	9	52.2	6	34.8
	9	52.2	9	52.2

IV. RESULTS AND DISCUSSION

4.1. Tensile Properties

Table 2 shows the variation of tensile strength of the composites with the different weight fractions of fly ash and graphite particles. It can be noted that the tensile strength increased with an increase in the weight percentage of fly ash and graphite. Therefore the fly ash particles act as barriers to the dislocations when taking up the load applied (Basavarajappa et al., 2004; Seah et al. 1995). The hard fly ash particles obstruct the advancing dislocation front, thereby strengthening the matrix (Suresh et al., 2003). However, as the size of the fly ash particles increased, there was decrease in tensile strength. Good bonding of smaller size fly ash particles with the matrix is the reason for this behavior. The observed improvement in tensile strength of the composite is attributed to the fact that the filler fly ash and graphite posses higher strength and toughness.

Tensile test specimen of diameter 37mm

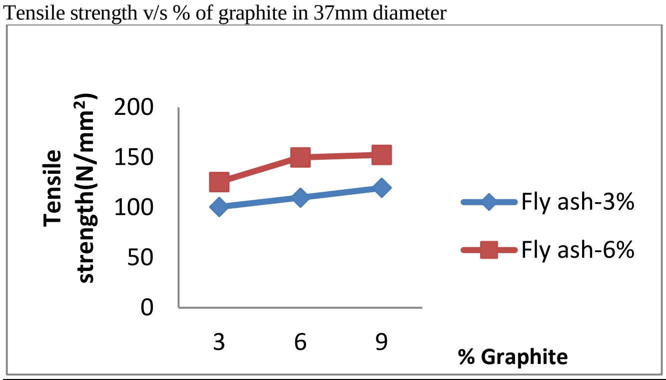


37mm Diameter Specimen after tensile test

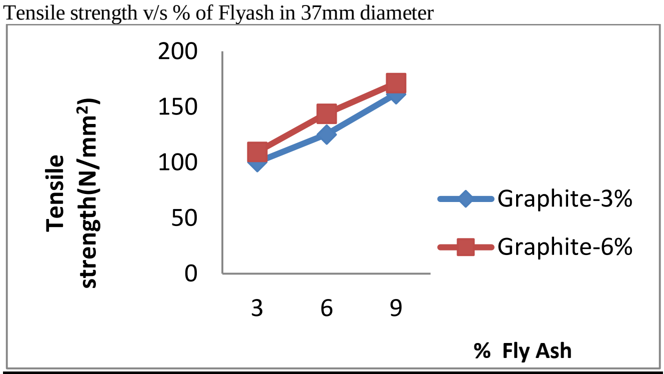
Table 3 shows the tensile test result of 37mmdiameter

Composition %	Peak load (KN)	Load at yield (KN)	Yield stress (N/mm^2)	% of Elongation	Tensile strength (N/mm^2)
Fly ash-3% Graphite-3%	11.80	9.90	100.12	2.78	119.33
Fly ash-3% Graphite-6%	16.10	14.10	127.40	2.62	145.10
Fly ash-3% Graphite-9%	18.40	15.00	122.22	2.72	149.92
Fly ash-6% Graphite-3%	20.20	17.40	155.90	2.40	180.99
Fly ash-6% Graphite-6%	17.40	14.80	156.26	2.86	183.4
Fly ash-6% Graphite-9%	24.00	2.80	179.04	2.58	206.97
Fly ash-9% Graphite-3%	17.30	14.90	147.77	1.86	171.57
Fly ash-9% Graphite-6%	21.90	19.90	165.30	3.78	181.98
Fly ash-9% Graphite-9%	26.90	23.80	230.31	4.48	260.30

Tensile strength v/s % of graphite in 37mm diameter



Tensile strength v/s % of Flyash in 37mm diameter

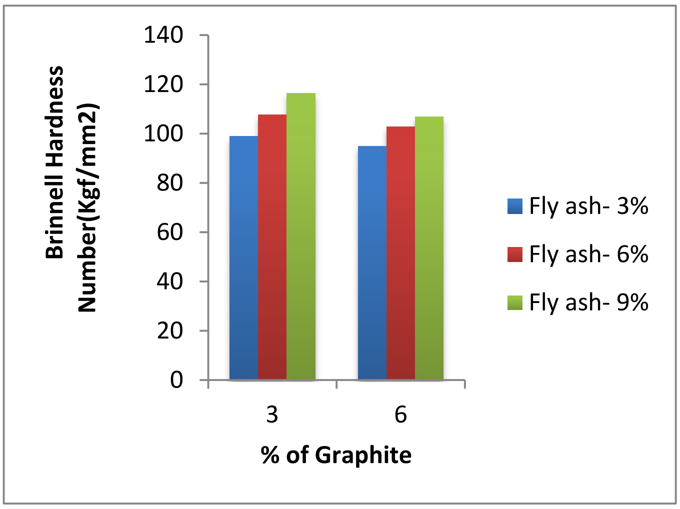


4.2. Hardness

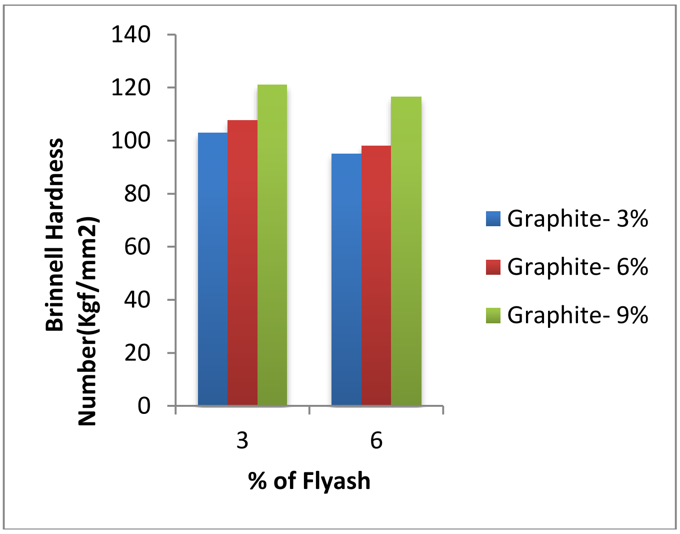
From table.3, it can be noted that the hardness of the composite increased with the increase in weight fraction of the fly ash and graphite particles. Thus the hard fly ash particles help in increasing the hardness of the aluminium alloy (Al6061) matrix Table 4 shows the hardness test result of 37 mm dia

Composition %	Ball Diameter 'D' (mm)	Load 'F' (kgf)	Diameter of Indentation 'd'(mm)	Average diameter (mm)	Brinell Hardness Number (kgf/mm^2)
Fly ash-3% Graphite-3%	5	250	1.82 1.76 1.70	1.76	92.88 99.471 106.86
Fly ash-3% Graphite-6%	5	250	1.85 1.70 1.55	1.70	89.70 106.86 129.66
Fly ash-3% Graphite-9%	5	250	1.63 1.69 1.57	1.63	132.58 108.16 125.87
Fly ash-6% Graphite-3%	5	250	1.90 1.74 1.82	1.82	84.86 101.85 92.80
Fly ash-6% Graphite-6%	5	250	1.80 1.73 1.66	1.73	95 103.070 112.23
Fly ash-6% Graphite-9%	5	250	1.86 1.54 1.70	1.70	88.70 130.95 106.86
Fly ash-9% Graphite-3%	5	250	1.84 1.76 1.68	1.76	90.71 99.47 112.23
Fly ash-9% Graphite-6%	5	250	1.76 1.51 1.63	1.63	99.47 136.34 116.53
Fly ash-9% Graphite-9%	5	250	1.60 1.55 1.65	1.60	121 129.22 113.34

Brinell Hardness Number v/s % of graphite Test results of 37mm diameter

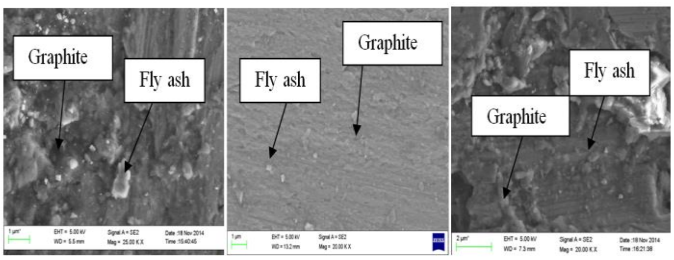


Brinell Hardness Number v/s % of Flyash Test results of 37mm diameter

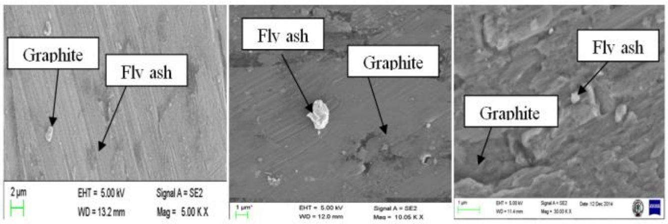


4.3 Microstructure

As the microstructure plays an important role in the overall performance of a composite and the physical properties depend on the microstructure, reinforcement particle size, shape and distribution in the alloy, prepared samples were examined using fly ash and graphite particulates can be seen in the SEM photomicrograph.



(a) (b) (c)



(d) (e) (f)

Fig. 4 SEM photomicrograph

(a)diameter 37mm flyash3%,graphite 3%

(b)diameter 37mm flyash 3% graphite 6%

(c)diameter 37mm flyash 3% graphite 9%

(d)diameter 37 mm flyash6% graphite 6%

(e)diameter 37mm flyash 9% graphite 3%

(f)diameter 37mm flyash 6% graphite 6%

4.4 Conclusions

MMC's containing up to 9% fly ash and graphite particles were easily fabricated. A uniform distribution of fly ash and graphite was observed in the matrix. The fluidity and density of the composites decreases, whereas the hardness increases with increasing percentage of fly ash and graphite particulates. The tensile strength and hardness strength increase with increasing percentage fly ash and graphite particulates. The dry sliding wear resistance wear resistance increases with increasing percentage of fly ash and graphite. In the slurry erosive wear test, the resistance to wear increases with increasing fly ash and graphite content. The MMC produced can be used for bearing applications, because of its good wear resistance.

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