Characterisation of Aluminium-Copper Alloy with Bamboo Leaf Ash and Graphite Metal Matrix Composites

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Abstract— **In the present day Aluminum metal matrix composites are widely used in the field engineering applications, especially in automobile, aerospace, marine and processing industries because of their improved higher specific strength, wear resistance, low density, high strength and good structural rigidity. Now a day's hybrid composites plays vital role in engineering applications. In this present work Al–4.5% Cu alloy was used as the matrix, bamboo leaf ash and graphite as the filler materials. The hybrid composite is produced by liquid metallurgical route (stir casting). This method is less expensive and very effective. The objective of this work is to predict the tensile strength, hardness, and wear behavior of the composites; Microstructure examination was done using a scanning electron microscope to obtain the distribution of bamboo leaf ash and graphite in the aluminum copper matrix. The results show the increase in hardness, tensile strength, and wear resistance with increasing the bamboo leaf ash and graphite content. Microstructure shows better bonding between matrix particles.**

Keywords*— *MMCs, bamboo leaf ash, Graphite, Stir Casting,* tensile test, *Wear behaviour

I. INTRODUCTION

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.(1) Aluminum-based alloys are widely used in automotive aerospace and industries because of their low densities and good mechanical and tribological properties [2]. Copper is one of the best alloying elements since the beginning of the aluminum metal matrix composites.

In the cast alloys the basic structure consists of dendrite in nature and possesses aluminum solid solution, with a variety of particles at the grain boundaries or inters dendritic spaces, forming brittle components with eutectics in nature. Most alloying elements can improve the modulus of elasticity of aluminum, but the increase is not remarkable for the aluminum-copper alloys (3). The modulus of elasticity at room temperature is of the order of 70-75 GPa and practically the same in tension and in compression. It changes regularly with temperature from a value of 76-78 GPa at 70 K to a value of the order of 60 GPa at 500 K. The Poisson ratio is of the order of 0.32-0.34. The Poisson ratio increases with increasing temperature (4-6). The design of low cost aluminum matrix composites (AMCs) using cheap reinforcing materials has continued to gather interest from researchers [7].

Currently, there have been efforts tailored to producing low cost AMCs, and the use of ashes produced from controlled burning of agro-wastes as reinforcement is receiving serious considerations [8]. Agro waste products such as baggase, rice husk, bamboo leaves, groundnut, and coconut shell among many others after harvesting are usually discarded in the environment due to poor recycling technologies and awareness leading to diverse environmental challenges [9].

Some of the advantages of these waste products are: very low cost of processing, ready availability at little or no cost, and often lower densities in comparison with most technical ceramics(such as silicon carbide, boron carbide, and alumina), benefit in conservation and protection of the environment(10). Stir Casting is a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring. The liquid composite material is then cast by conventional casting methods and may also be processed by conventional Metal forming technologies (11).

This research work investigates the hardness, tensile and wears behaviours of bamboo leaf ash and graphite hybrid reinforced aluminum copper alloy matrix composites. This study is motivated by the prospect of developing low cost AMCs suitable for use in engineering applications where high wear properties are desired.

II. MATERIALS AND METHOD

A. *Materials method*

Aluminum copper alloy with chemical composition presented in Table 1 was selected as Al matrix for this study. Bamboo leaf ash (BLA) particles having average particle size of 50µm, graphite (<50µm) processed by controlled burning of dry bamboo leaves were used as reinforcement for the Aluminum copper alloy. Magnesium is used for improving wetting between the Aluminum copper alloy and the reinforcement during melting was also procured.

In this research, the liquid metallurgical route (stir casting system) was conducted for production of castings. A stir casting setup which consisted of a resistance furnace and a stirrer assembly is used to synthesis the combination of matrix and reinforcements. Al-4.5wt%Cu alloy commercially prepared was melted in a resistance heated furnace and casted in a crucible. Table 1 shows the chemical composition of base alloy, analyzed by optical emission spectrometer. The density of bamboo leaf ash measured is 1.8 g/cm^3 with the particle size 50µm. Graphite particle size which is used to fabricate the composite had an average of 50µm and density is 2.01g/cm3.

TABLE 1. CHEMICAL COMPOSITION OF AL–4.5% CU ALLOY IN WEIGHT PERCENTAGES

Element	Percentage
Cu	4.5
Mg	1.00
Si	0.60
Fe	0.65
Mn	0.10
Ti	0.10
Zn	0.20
Al	Balance

B. *Preparation of bamboo leaf ash (BLA)*

The bamboo leaf ash was prepared following procedures and precautions reported by Alaneme et al [12]. Dry bamboo leaves were gathered from the environment of park lands near the shivananda circle having a large mass of bamboo trees. The collected bamboo leaves were placed in a metallic drum and fired in open air to allow for thorough combustion.

The ash produced from the burning process was allowed to cool for 24 hours before removal from the drum. The ash was then conditioned using a muffle furnace at a temperature of 650^{o}C for 3 hours in accordance with [13]. Sieving of the bamboo leaf ash was then performed using a sieve shaker to obtain ashes with mesh size under 50 µm. The chemical composition of the bamboo leaf ash is presented in Table 2.

TABLE 2. CHEMICAL COMPOSITION OF BAMBOO LEAF ASH IN WEIGHT PERCENTAGES

Element	Percentage
SiO2	76
Al2O3	4.2
CaO	7.25
MgO	1.9
K2O	5.8
Fe2O3	1.4
TiO2	0.20

C. *Preparation of composites*

Fig.1. dried bamboo leaves

Al-4.5wt%Cu alloy which is commercial available ingots pieces was charged into the crucible, melted in electrical resistance furnace, and heated to about 800°C till the entire alloy in the crucible was melted. The bamboo leaf ash and graphite particles were preheated to 200°C for two hours to remove moisture. The cast iron mould of size 37mm diameter with 200mm length was used for the preparation of cast blanks. After the molten metal was fully melted, the stirrer was lowered into the melt slowly to stir the molten metal at the speed of 450 rpm. Tilt angles and movement of stirrer from top to bottom in the crucible were used to obtain vortex strong enough to disperse the reinforcements into the melt. The preheated bamboo leaf ash and graphite particles were added to the vortex between liquids. The stirring was continued for another 3 minute even after the completion of particle feeding. The temperature was also monitored simultaneously during stirring. After through mixing of matrix and reinforcements, the melt was poured into preheated die cavity and solidification was carried out with open air nearly two hours.

D. *Testing for Mechanical Properties*

1) *Brinell hardness test*

Hardness measurements were performed using a Brinnel hardness tester with a load of 250 kgf as per ASTM-E10-01. Hardness values were averaged over three measurements taken at different points on the cross-section.

2) *Tensile test*

Tensile tests were carried out using samples prepared according to ASTM-E-8 standard. These tests were conducted using a computerized universal testing machine (UTM) with 60KN capacity.

E. *SEM analysis*

The SEM micrographs of composites are shown in fig. The size, density, type of reinforcing particles, and its distribution have a pronounced effect on the properties of particulate composites. The variables affecting the distribution of particles are solidification rate, fluidity, type of reinforcement, and the method of incorporation. It is essential to get particles uniformly throughout the casting during particulate composite production. The first task is to get a uniform distribution of particles in the liquid melt and then to prevent segregation of particles during pouring and progress of solidification. One of the major requirements for uniform distribution of particles in the melt is its wet ability.

Figures 2,3 and 4 reveals the microphotographs of aluminum-copper reinforced with Graphite and Bamboo leaf ash particulates. From figure it is Clear that, the distribution of reinforcing particulates in both the composites is fairly uniform in all the compositions studied while clustering of the particles were seen at few locations.

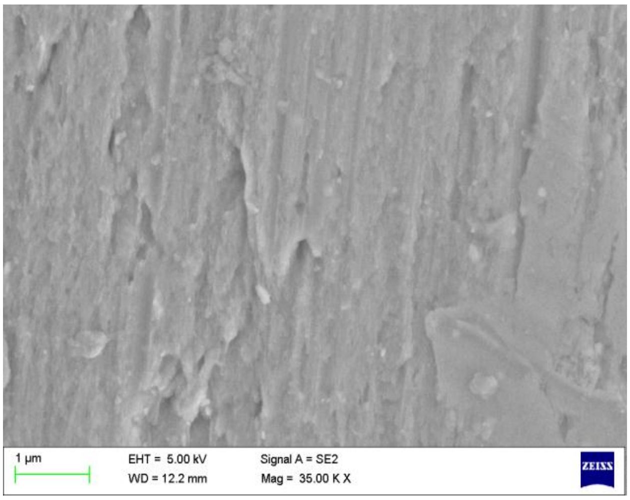

Fig. 2. SEM analysis of 2 Wt % of BLA and 2 Wt % Gr

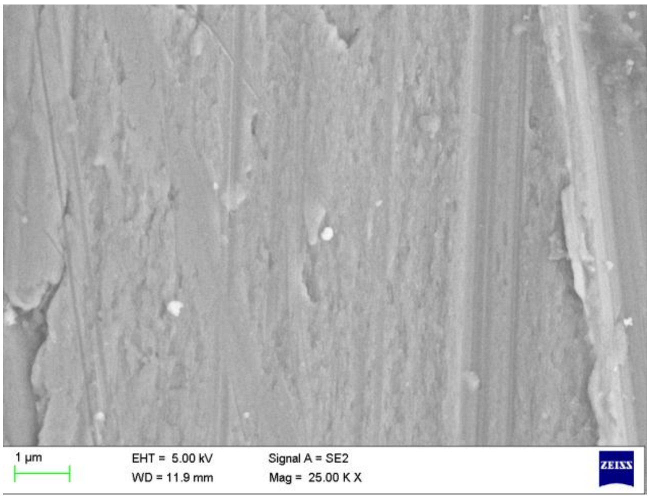

Fig. 3. SEM analysis of 4 Wt % of BLA and 4 Wt % Gr

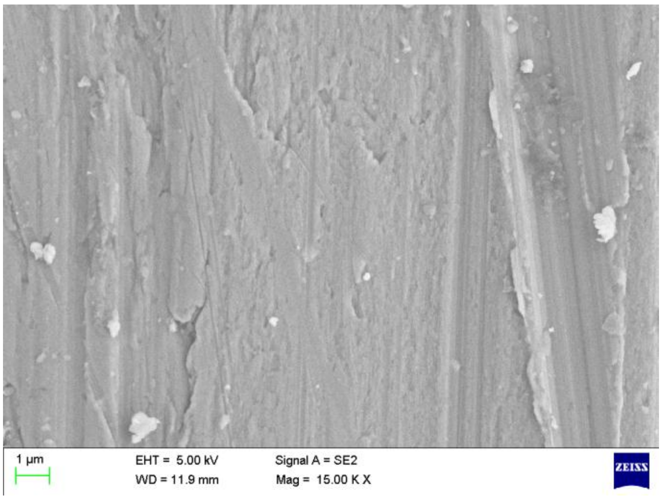

Fig. 4. SEM analysis of 6 Wt % of BLA and 6 Wt % Gr

F. Result and discussion

1) Hardness test

Table 3 and figure 4,5,6 shows the results of Brinnel hardness tests conducted on matrix and the Al-Cu alloy with BLA and graphite hybrid composites containing varying weight percentages of BLA and graphite particles i.e. 2, 4 and 6 wt%. The Brinnel hardness was measured on the polished samples using 5 mm indenter with a load of 250kgf and the value reported is average of 3 readings taken at different locations. A significant increase in hardness of the alloy matrix can be seen with addition of BLA and graphite particles. The higher value of hardness of composites indicates that the existence particulates in the matrix have improved the overall hardness of the composites.

This is true due to the fact that matrix is a soft material and the reinforcement particle being hard, contributes positively to the hardness of the composites. The presence of stiffer and harder graphite reinforcement leads to the increase in constraint to plastic deformation of the matrix during the hardness test. Thus increase of hardness of composites could be attributed to the relatively high hardness of graphite itself. Further from the graph it can be observed that the hardness of Al-Cu/BLA/Graphite hybrid composites slowly increased by increasing the content of bamboo leaf ash and graphite.

TABLE 3. HARDNESS TEST RESULT

Sl no	**Composition %**	**Ball Diameter "D" (mm)**	**Load 'F' (kgf)**	**Diameter 37mm**	
				Mean diameter of indentation 'd' (mm)	***Brinell hardness number (kgf/mm^2)***
1	BLA-2% Gr-2%	5	250	1.83	91.7
2	BLA-2% Gr-4%	5	250	1.8	95
3	BLA-2% Gr-6%	5	250	1.76	103
4	BLA-4% Gr-2%	5	250	1.63	99.4
5	BLA-4% Gr-4%	5	250	1.7	106.8
6	BLA-4% Gr-6%	5	250	1.73	112.2
7	BLA-6% Gr-2%	5	250	1.56	116
8	BLA-6% Gr-4%	5	250	1.6	121
9	BLA-6% Gr-6%	5	250	1.66	126
10	Al-cu	5	250	1.86	88.7

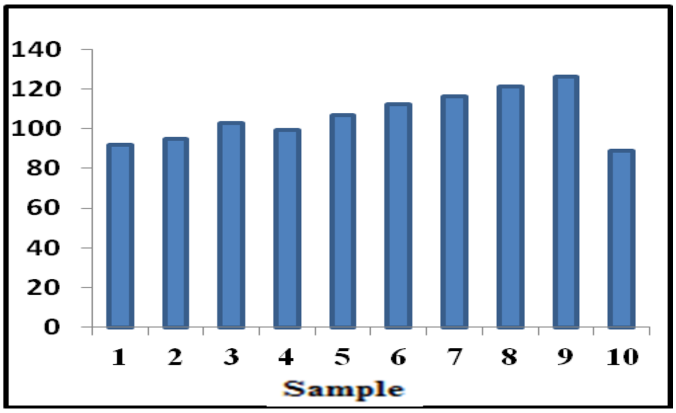

Fig. 5. Hardness results composites

From the above table 3 and fig 5 it shows that the hardness of the composite samples is increases with increasing of reinforcements compare to the base matrix.

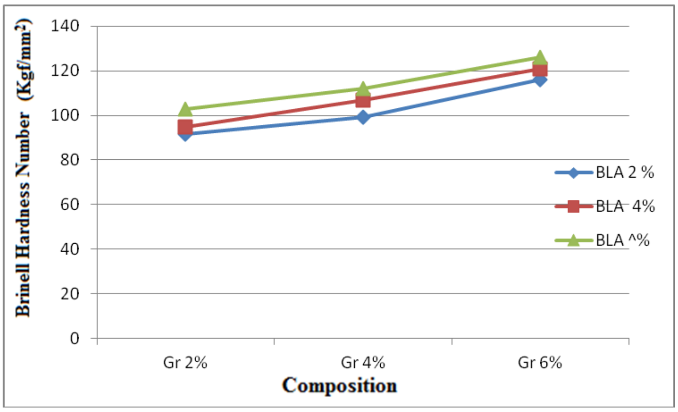

Fig. 6. hardness Vs BLA result

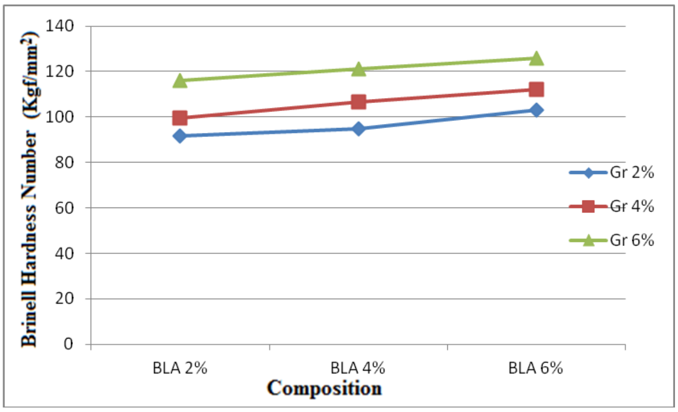

Fig. 7. hardness Vs graphite result

By observing the above Fig 6 and 7 the hardness of the prepared composite samples increases by increasing the reinforcements, the addition of graphite is more effective reinforcement compare to the bamboo leaf ash

2) Tensile test

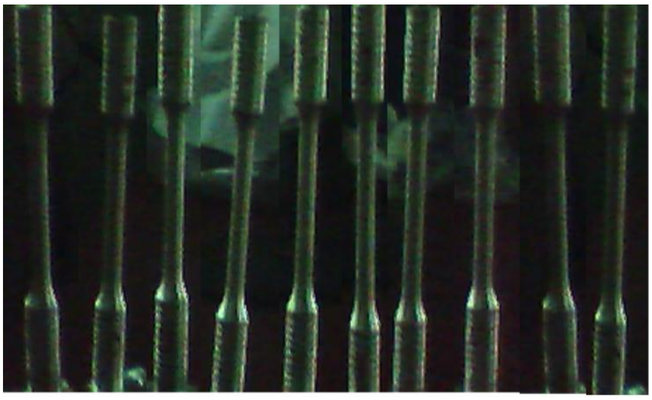

Fig. 8. Tensile specimens before the test

Fig. 9. Tensile specimens after the test

Table 4: shows the variation of tensile strength of the composites with the different weight fractions of bamboo leaf ash and graphite particles. It can be noted that the tensile strength increased with an increase in the weight percentage of bamboo leaf ash and graphite. Therefore the graphite particles act as barriers to the dislocations when taking up the load. The hard graphite particles obstruct the advancing dislocation front, thereby strengthening the matrix. However, as the size of the graphite particles increased, there was decrease in tensile strength. Good bonding of smaller size bamboo leaf ash particles with the matrix is the reason for this behaviour. The observed improvement in tensile strength of the composite is attributed to the fact that the filler bamboo leaf ash and graphite posses higher strength and toughness.

TABLE 4. TENSILE TEST RESULTS

Composition %	Peak load (KN)	Load at yield (KN)	Yield stress (N/MM^2)	% of elongation	Tensile strength (N/MM^2)
BLA-2% Gr-2%	14.50	13.20	122.90	2.12	121.38
BLA-2% Gr-4%	16.30	14.50	117.52	2.03	141.2
BLA-2% Gr-6%	9.60	8.70	95.02	2.18	148.8
BLA-4% Gr-2%	15.10	13.20	151.56	2.36	170.3
BLA-4% Gr-4%	18.40	16.10	150.10	2.60	181.59
BLA-4% Gr-6%	24.70	22.41	225.41	4.08	201.8
BLA-6% Gr-2%	15.60	13.60	142.57	3.26	189.08
BLA-6% Gr-4%	19.20	18.30	160.10	3.58	181.88
BLA-6% Gr-6%	22.50	27.50	174.14	4.78	158.32
Al-cu	12.18		88.28	2.04	99.4

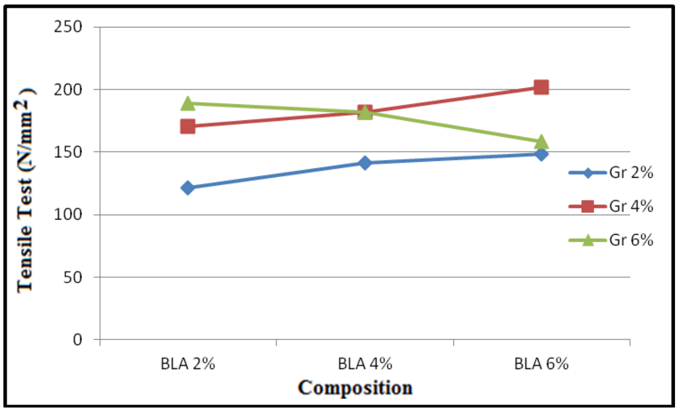

Fig: 10.Tensile strength Vs graphite

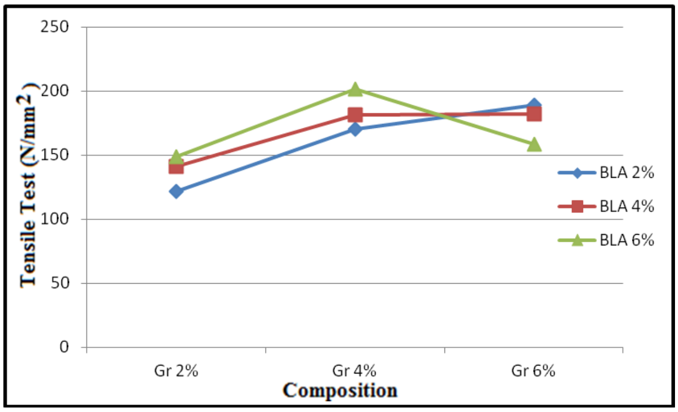

Fig. 11.Tensile strength Vs BLA

From the above fig 10 and 11 it shows that the tensile test of the prepared composite samples increases up to 4% of bamboo leaf ash and 6% of graphite.after that it slowly decreses by increasing of reinforcements but compare to the base matrix composites samples results are increases. From the above fig it show that the graphite is effective reinforcements compare to the bamboo leaf ash.

III. CONCLUSION

- Aluminium based hybrid metal matrix composites have been successfully fabricated by stir casting method by addition of reinforcement combined with preheating of particulates.
- Hardness of the prepared composites is higher than the base Aluminium-copper alloy.
- Tensile strength of prepared composites is higher in case of composites up to BLA 4% and Graphite 6 wt%, after this slowly decreases but higher than compared to base matrix. This causes decrease in percentage elongation as compared to base alloy. Addition of graphite content increased the percentage of elongation compared to composites containing BLA and graphite particles.
- Addition of 6wt% graphite increases the tensile strength considerably with respect to base matrix AL-Cu alloy.
- The distribution of reinforcing particulates in the composites is honestly uniform in all the compositions studied while clustering of the particles was seen at few locations.

IV. REFEERENCE

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