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Development of Bamboo Stem Ash - Al-Hybrid Reinforced with SiC Produced by Spin Casting Technique

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ABSTRACT: *Various materials have been combined to achieve some intended properties. This concept holds true for composite materials. Aluminum matrix composite is one of the emerging metal matrix composites that can be modified to possess some unique properties such as specific strength and good wear resistance. Spin casting is a processing route whose products are found to possess good mechanical properties. In this study, aluminum hybrid composite was produced from aluminum 6063 reinforced with silicon carbide (SiC) and bamboo stem ash (BSA) via spin casting technique. Microstructure and mechanical properties of the developed hybrid composites were investigated. Microstructural studies show that the reinforcements were uniformly distributed within the aluminum matrix. The tensile strength of the hybrid composites increased gradually with BSA content up to 7.5 wt% when optimum was attained; fracture toughness of all hybrid composite were superior; and wear resistance of the composite increased with SiC content.*
Keyword: *Spin casting, strengthening, reinforcement, MMC, fracture toughness.*

I. INTRODUCTION

The development of low cost and high performance advance engineering materials for various engineering applications has continued to draw the attention of researchers in material engineering field, several authors have reported about the design of metal matrix composites. Metal matrix composites (MMCs) possess improved properties such as high specific strength; specific modulus, damping capacity and better wear resistance compared to unreinforced metal. One of the emerging metal matrix composites with wide range of applications is aluminium matrix composites (AMCs).Aluminium matrix composite possess some unique properties such as high specific strength, good wear resistance, elevated temperature toughness, low density, high stiffness, low coefficient of thermal expansion, corrosion and high temperature resistance among others when compared with its monolithic counterpart (Alaneme*et al*., 2013). These unique properties are very useful for the fabrication of a wide range of components and parts utilized in engineering and other industrial applications. Several authors have centered their research work on aluminium matrix composite materials because of its' wide range of applications especially in the design of components for automobiles, aircrafts, marine structures and facilities, sports and recreation, defense assemblies among many other areas of applications.

The application areas of Al based composites is expected to continue growing, this is possible by virtue of the attractive property spectrum possessed by AMCs and the relative low cost of production in comparison with other competing MMCs (such as Magnesium,Copper,Titanium and Zinc) for similar applications (Surappa*et al*., 2003). Proper selection of reinforcing material for Al matrix composite material and techniques process are very important factors in ensuring that desired property combinations are achieved.However, very few researchers from developing countries have harnessed the superior strength, lower cost and density advantages of these agro wastes. This research work is aimed to the possibility of developing high-performance low-cost Aluminum hybrid composite reinforced with Bamboo stem ash and silicon carbide. The use of BSA in this study is as a result of its low density (0.5-0.725 g/cm³) in comparison to SiC (3.18 g/cm³. it is available in large quantity and distribution in most part of the developing countries, and it's cheaper processing cost (Miracle *et al., 2005*). MMCs are not fabricated by conventional alloying methods suitable for metals; since, such a process would mar the essence of a composite. In alloys the phases are not chemically and physically distinct. But in a composite, such phases are intentionally kept distinct, to exploit the properties of the constituents to the fullest (Prabu*et al.*, 2006), The volume fraction of porosity, and its size and distribution in a cast metal matrix composite play an important role in controlling the material's mechanical properties.In every part of the world, various materials have been combined to achieve some intended properties. This concept holds true for a genre of materials called Composite materials where in, various types of matrices may be combined with reinforcements which contribute to the enhancement of the properties. This alteration in properties can be controlled by many ways, viz. controlling the matrix and reinforcement quality, their proportion or the fabrication route. This flexibility in manufacturing allows one to develop composites with varying properties in a precisely controlled fashion (Garcia *et al*., 2009; Isselin*et al*., 2010). It is the superiority of properties that has triggered the penetration of composite materials into all fields of manufacturing. 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) which could be catered for by a controlled and well supervised fabrication method.

II. METHODOLOGY

Mould Preparation For Spin Casting

The mould for the spin casting was prepared, using sand and additives (bentonite and water). The mould parting line was formed at this stage. Mould parting sand, was sprayed on the surface of the cope and drag of the mould and then coupled by nuts arranged around the edge of the mould compartment. The gates and runner system were carefully made into the sand mould with a scalpel. Air vent was also drill into the cavity to aid the removal of trapped air or gases. The coupled mould compartment was placed on the casting unit of the spin casting machine.

The reinforcing filler was produced by burning some dried bamboo stem using a metallic drum which served as burner. The dried bamboo stem was ignited using charcoal and allowed to burn completely inside the drum. The ash obtained from the process was then conditioned in a furnace at a temperature of 550°C for 4 hours to reduce the volatile and carbonaceous constituents of the ash. Sieve size analysis was carried out on the conditioned ash using a digital sieve shaker. Particle sizesof 50µm and below were utilized as the reinforcement. Aluminium ingot was cut into small sizes to fit into the pot of cupola furnace. The quantity of bamboo stem ash (BSA) and Silicon Carbide (SiC) were determined by charge calculation to give 10 wt% reinforcement consisting of varying ratios of BSA - SiC in the order of 0:10, 2.5:7.5, 5.0:5.0, 7.5:2.5 and 10:0 to produce the composites.

Since $Density = \frac{mass}{volume}$

$$mass = density \times volume$$

COMPOSITION 1

$$massofcharge = 25.63cm^3 \times 2.5g/cm^3 = 64.075g$$

$$for\ 2\ samples \rightarrow 2 \times 64.075 = 128.15g$$

$$massofAl = \frac{90}{100}(128.15) = 115.34g$$

$$50\%\ allowance = \frac{50}{100}(115.34) + 115.34 = 173.0g$$

$$massofBSA = \frac{10}{100}(128.15) = 12.82g$$

$$50\%\ allowance = \frac{50}{100}(12.82) + 12.82 = 19.23g$$

This calculation was repeated for other compositions to get compositions 2 to 5 which is presented in Table 1.

Table 1: Mass of the matrix and the reinforcement for each composition

	Mass of Al (g)	Mass of BSA (g)	Mass of SiC (g)
COMPOSITION 1	173.00	19.23	0.00
COMPOSITION 2	177.16	14.76	4.92
COMPOSITION 3	181.65	10.09	10.09
COMPOSITION 4	186.15	5.17	15.51
COMPOSITION 5	190.30	0.00	21.15

Preheating separately at a temperature of 250°C of the BSA and silicon carbide was done to aid removal of moisture content and improves wettability with the molten Al. The Aluminium was melted in the furnace, at temperature of 670°C, the Aluminiummelted completely. At this stage, the preheated BSA and silicon carbide preheated were charged into the melt while stirring of the slurry was performed manually for 5-10 minutes. The process progressed with the superheating of the composite. Prior to poring for casting operation, the spin casting machine was switched on and set at 700 rpm. During the casting process, the melted composite was poured in the mold which spinnedalong its central axis for 30 minutes (to obtain homogenous mixture of the reinforcement with the aluminium matrix). After this, the spin casting machine was switched off and the cast composite was left to cool to room temperature for the cast composite to be removed. This procedure was repeated for all other compositions.

III. RESULTS AND DISCUSSION

Figure 1 shows the representative optical micrographs for Aluminum hybrid composites reinforced with BSA and SiC. It was observed that the reinforcing particles (BSA and SiC) are visible and uniformly dispersed in the Aluminum matrix. From the figure, it was observed that the distributions of reinforcements in the matrix are fairly uniform. The photomicrograph also clearly reveals the increased filler contents in the composites.

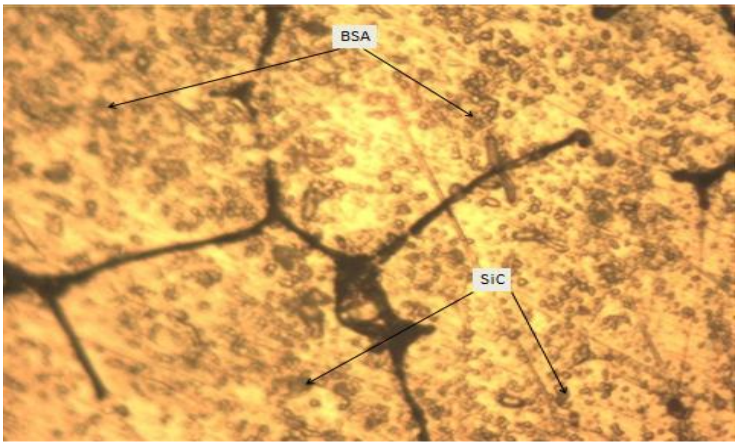

Figure 1: Photomicrograph of AL-SiC/BSA (2.5 wt% BSA: 7.5 wt% SIC) at**x**400

The stress strain curve for the hybrid composite is represented in Figure 2 while the Ultimate Tensile Strength (UTS) is presented in Figure 3. It can be deduced from Figures 2 and 3 that the material with highest UTS is composition 1 which contains 10wt% BSA, while composition 2 which has the lowest UTS is the least ductile which may be due to the wettability of the reinforcements with the aluminium matrix. It is clear that addition of BSA leads to improvement in the ultimate tensile strength of the aluminium composite as compared with others. The presence of Magnesium in BSA could be responsible for improving the strength of the composites significantly.

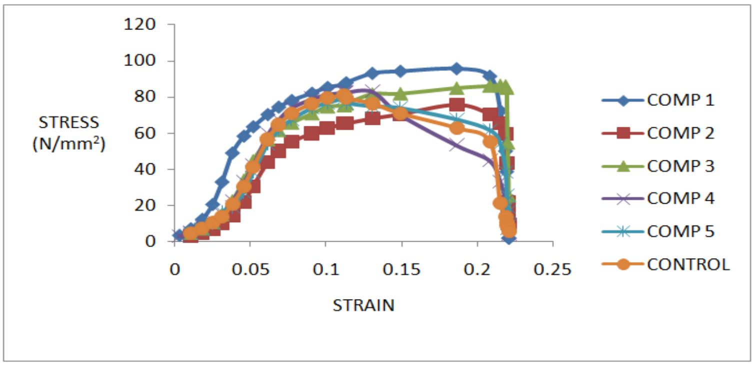

Figure 2: Plot ofStress-strain curves

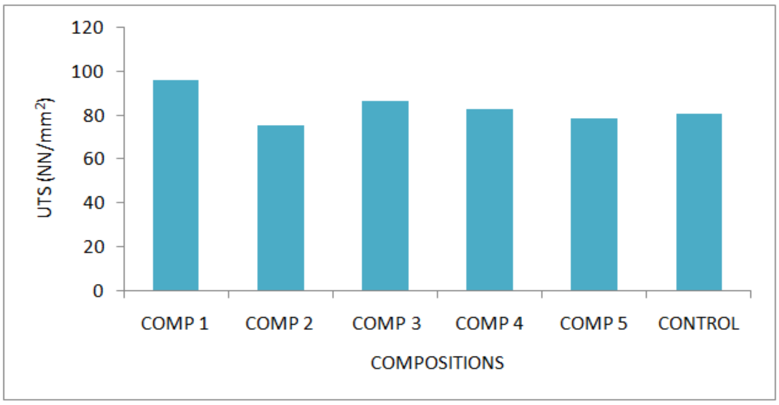

Figure 3: Chart for ultimate tensile strength

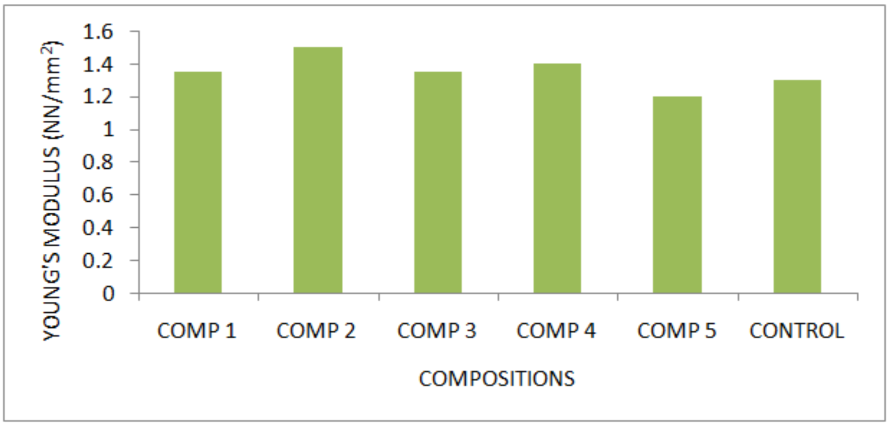

Figure 4: Chart of young's modulus

Figure 4 shows that composition 2 which contains 7.5% BSA and 2.5% SiC exhibited highest modulus of elasticity and composition 5 with 10% SiC has the least modulus of elasticity, while there was no pronounced difference in the young's modulus of composition 1 (10% BSA), 3 (5% BSA and SiC), 4 (2.5% BSA and 7.5% SiC), and the control sample. Thus, composition 2 has the highest stiffness, while composition 5 has the least stiffness. This trend was due to thepresence of BSA whose major constituent was silica. Thus, there was aslightreduction in the direct strengthening effect usually expected from the transfer ofload from the matrix to the supposedly harder and stiffer particulates (Chawla, 2001).

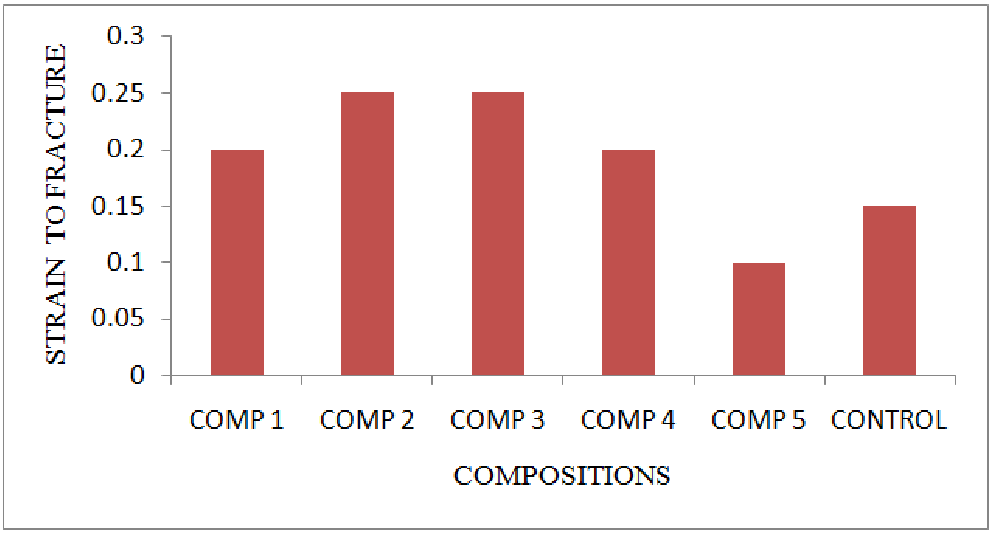

Figure 5: Chart of Strain to Fracture

Figure 5 shows that composition 2 (7.5wt% BSA and 2.5wt% SiC) and 3 (5wt% BSA and 5wt% SiC) exhibited same strain to fracture while composition 5 (7.5wt% SiC and 2.5wt% BSA) exhibited the least strain to fracture.

IV. ANALYSIS OF TENSILE TEST RESULT

From Figures 2, 3 and 5, the ultimate tensile strength (UTS), young's modulus and strain to fracture of the composites is found to increase as the content of BSA particulates is increased up to 5% by weight. The work of (Singla *et al*., 2009) showed that when SiC increases to above 2.5%, properties such as tensile strength reduces. This happens because the increasing quantities of SiC particles react with each other and settle down, thereby contributing to a local reduction in density (of SiC particles). In another study, (Neelima*et al*., 2011) also compare the percentage of SiC content with tensile strength and elongation wherein they found that the tensile strength increases with the SiC content up to 1.5% after which it drops. The percentage of elongation was proportional to the SiCpercentage.

Wear Test Result

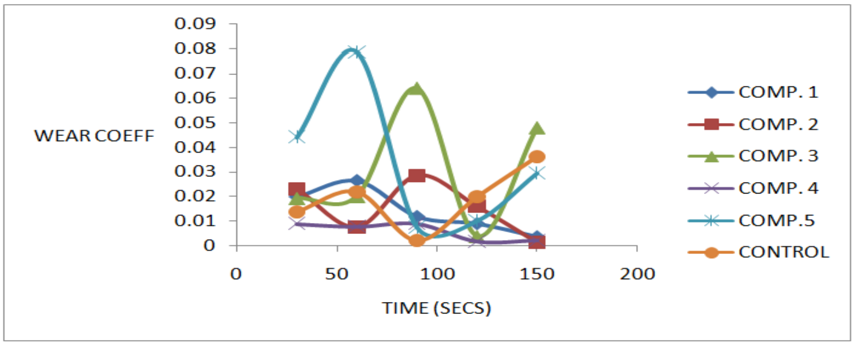

Figure 6: Graph of Wear Coefficient against Time at L_0=5.95N

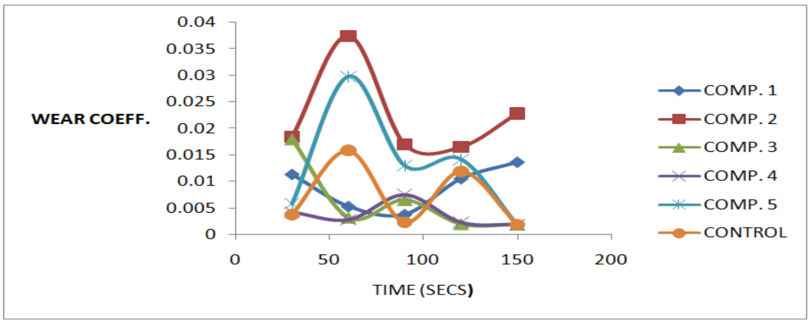

Figure 7: Graph of Wear Coefficient against Time at L_0=9.93N

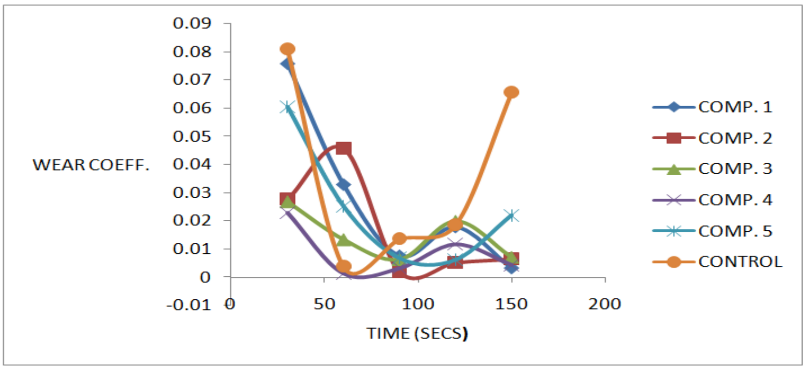

Figure 8: Graph of Wear Coefficient against Time at L_0=15.89N

Figures 6-8 showed the coefficient of friction for wear behaviour of the developed hybrid composites at different loading under dry condition. The coefficient is determined by the ratio of the friction force to the loading force on the ball. The results show that the COF decreases with increasing SiC content. Lower friction means lower wear rate and that translate to higher wear resistance. It can be deduced from the graphs that composition 4 (2.5wt% BSA and 7.5wt% SiC) is more stable and exhibited lowest wear coefficients which makes it to have the highest resistance to wear which is due to combining effect of BSA and increasedSiC content (Singh *et al.*, 2012). Poor wear resistance obtained from other combination could possibly be due to poor wettability of the combined reinforcements with the matrix or since both reinforcements induces hardening effect on the composites, at the incorporation of sliding effect from the ball, there will be breaking of bonds which will lead to materials pulling off, since these pull off materials are not removed from the sliding surface but rather continued to be glide and smeared on the surface, third body wear mechanism is introduced which will invariably increase the wear rate of the material (Younesi and Bahrololoom, 2010; Olaniran et al., 2014 . It was evident that further addition of SiC; sample 5 (100wt% SiC) has the highest wear coefficients thus having lowest wear resistance. This is because SIC is hard and follows the illustration provided earlier as third body wear mechanism is introduced.From this research, it was observed that an increment in SiC content above 7.5wt% of the 10 wt% reinforcement of the Aluminium hybrid composite reduces the wear resistance significantly.

V. CONCLUSION

The microstructural studies and mechanical behavior of Al- BSA/SiC matrix composites containing 0:10, 2.5:7.5, 5:5, 7.5:2.5, and 10:0wt% Bamboo Stem Ash and Silicon Carbide as reinforcement were investigated. The results show that:

1. The Fracture toughness of all hybrid composite composition was superior to that of the single reinforced composites and the non-reinforced.
2. The Tensile strength of the hybrid composites increased gradually with BSA content but a sudden reduction takes at Composition 2(7.5wt%BSA: 2.5wt%SiC) which is due to improper wettability between the reinforcement and matrix phase.
3. The resistance to wear of the Al-BSA/SiC composites increases with SiC content up to 7.5wt%.
4. From Microstructural studies, it was concluded that the reinforcements are uniformly distributed in the Aluminium matrix, which influences the mechanical properties.
5. BSA has great promise to serve as a complementing reinforcement for the development of low-cost high-performance aluminum hybrid composites.

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