

# An investigation of the mechanical properties of organic silica, bamboo leaf ash and rice husk reinforced aluminium hybrid composite

## Abstract

Aluminium Metal Matrix Composites has continually generated a lot of interest due to the versatility of its application, lower cost of production and its outstanding properties. This study was carried out on the mechanical behavior of an aluminium 6063 based composite reinforced with bamboo based leaf (BLA) and rice husk ash (RHA). The chemical composition of each of the Al-Mg-Si alloy, BLA and RHA was determined; different kinds of characterization and microstructural analysis were also carried out to investigate the mechanical properties. The ultimate tensile strength values of the developed composites revealed that 10wt% reinforced composites are superior to that of unreinforced alloy. Similarly, the yield strength values of the reinforced composites are superior to that of unreinforced alloy. 78.4% and 80.0% improvement were observed in comparison with unreinforced alloy. The % elongation values were invariant to the weight ratio of BLA and RHA. Among all the composites investigated, 10wt% composites reinforced with 75% BLA and 25% RHA together with 10wt% composites reinforced with equal percentage of BLA and RHA exhibited the highest hardness value of 46.4 and 42.2 respectively. Also, from the optical microstructures of the Al-BLA/RHA-8wt% and 10% hybrid composite, it is observed that the reinforcing particles (BLA and RHA) are visible and clearly delineated in the microstructure. The particles are fairly well distributed in the Al matrix and signs of particle clusters are minimal.

**Keywords:** aluminium, hybrid mmcs, organic silica, bamboo leaf ash, composites, rice husk ash, Al 6063

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**Abbreviations:** BLA, bamboo based leaf; RHA, rice husk ash; MMCs, metal matrix composites; AHCs, aluminium hybrid composites

## Introduction

The availability of diverse materials has posed a big challenge of materials selection for different engineering applications.<sup>1</sup> However; this has enhanced the preference for affordable high performance materials with requisite quality. Metal Matrix Composites (MMCs) has emerged as a viable alternative to different conventional materials.<sup>2</sup> The application of these composites have been established in different industries such aerospace, marine, defense and automobile. Metals such as copper, aluminium, magnesium and their alloys are the most commonly used MMCs due to their light weights. The unique properties of these metals are combined with different kind of reinforcement materials to produce composite materials of distinct properties.<sup>3-6</sup> Aluminium based composites has continually generated a lot of interest judging from the available volume of literature. The versatility of its application, lower cost of production and its outstanding properties have distinguished Al based composites and it has remained the most used MMC.<sup>2</sup> The reinforcement materials selected with Al MMC is very crucial in harnessing the desired property. In different research, numerous reinforcement materials such as fly ash, silicon carbide, alumina, silica, graphite, mica among others have been selected with Aluminium MMCs.<sup>7</sup>

However, the areas of application of Al based composites is expected to continue growing. Therefore, different combinations of important reinforcement materials particularly agro waste products including bamboo leaf ash and rice husk require further study.

Different literatures have studied the potentials of agro waste products as adequate reinforcement materials, findings have shown that Al based composites reinforced with synthetic ceramics including alumina and silicon carbide have superior properties in comparison to the agro waste ash reinforced grades. In this paper, our aim is to consider the potentials of bamboo leaf ash (BLA) and Rice Husk Ash (RHA) as complimenting reinforcement for the development of low cost-high performance Aluminium Hybrid Composites (AHCs).

## Materials and methods

### Materials

Al-Mg-Si alloy billets - with chemical composition determined using spark spectrometric analysis as shown in Table 1 was selected as Al matrix for this investigation. For the hybrid reinforcing phases, bamboo leaf ash (BLA) and rice husk ash (RHA) (<50µm) derived from controlled burning and sieving of dry bamboo leaves and rice husk were used as reinforcement for the Al matrix. Magnesium was procured for use in improving wettability between the Al matrix and the reinforcements.

**Table 1** Chemical composition of Al-Mg-Si alloy billet in weight percentages

Elements	Si	Fe	Cu	Mn	Mg	Zn	Ti	Ni	Sn	Pb	Ca	V	Al
wt%	0.4	0.22	0.008	0.011	0.396	0.02	0.013	0.01	0.002	0.001	0.002	0.003	98.88

## Methods

**Preparation of bamboo leaf ash (BLA):** Dry bamboo leaves were gathered from FUTA environment near the forest 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 24hours before removal from the drum. The ash was then conditioned using a muffle furnace at a temperature of 650°C for 3hours. Sieving of the bamboo leaf ash was then performed using a sieve shaker to obtain ashes with mesh size under 50µm.

**Preparation of rice husk ash (RHA):** A simple metallic drum with perforations to allow for air circulation to aid combustion was used as burner for the preparation of the RHA. Dry rice husks were placed inside the drum while charcoal, which served as the fire source was used to ignite the rice husk. The husk was left to burn completely and the ashes removed 24hr later. The ash was then conditioned by heat-treating the ash at a temperature of 650°C in an electric furnace for 180mins to reduce the carbonaceous and volatile constituents of the ash.

**Composite production:** Two step stir casting process was utilized to produce the composites. The process started with the determination of the quantities of RHA and BLA required to produce 6 and 10 wt% reinforcement consisting of 0:1, 1:2, 1:4, 1:6, and 1:8 RHA and BLA weight percents, respectively and marked as B, C, D, E and F while the unreinforced was marked as A. The RHA and alumina were initially

preheated at a temperature of 250°C to remove moisture and to help improve wettability with the Al–Mg–55Sn Si alloy melt. The Al–Mg–Si alloy ingots were charged into a gas-fired crucible furnace and heated to a temperature of 750±30°C (above the liquids temperature of the alloy) to ensure the alloy melts completely. The liquid alloy was then allowed to cool in the furnace to a semi solid state at a temperature of about 600°C. The preheated RHA and BLA particulates were added at this temperature (600°C) and stirring of the slurry was performed manually for 5–10min. The composite slurry was then superheated to 800±30°C and a second stirring performed using a mechanical stirrer. The stirring operation was performed at a speed of 400rpm for 10min to help improve the distribution of the particulates in the molten Al–Mg–Si alloy. The molten composite was then cast into prepared sand moulds inserted with chills. Lathe machine was used to produce the composite into a smooth rod-like shape and to reduce the samples into the dimensions suitable for mechanical testing. Microstructural examination was carried out using Zeiss Metallurgical Microscope with accessories for image analysis. Hardness, tensile and wear testing were also carried out on the specimens. The fracture toughness evaluation was done also.

## Results

### Chemical composition of materials

The chemical composition of Al–Mg–Si alloy billet in weight percentages is shown in Table 1, while Tables 2 & Table 3 presents the chemical composition of BLA and RHA.

**Table 2** Chemical composition of bamboo leaf ash in weight percentages

Composition	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	ZnO	CaO	MgO	Na <sub>2</sub> O	K <sub>2</sub> O	Fe <sub>2</sub> O <sub>3</sub>	TiO <sub>2</sub>	Others
wt%	76	4.2	1.18	7.25	1.9	0.22	5.8	1.4	0.20	1.85

**Table 3** Chemical composition of rice husk ash in weight percentages

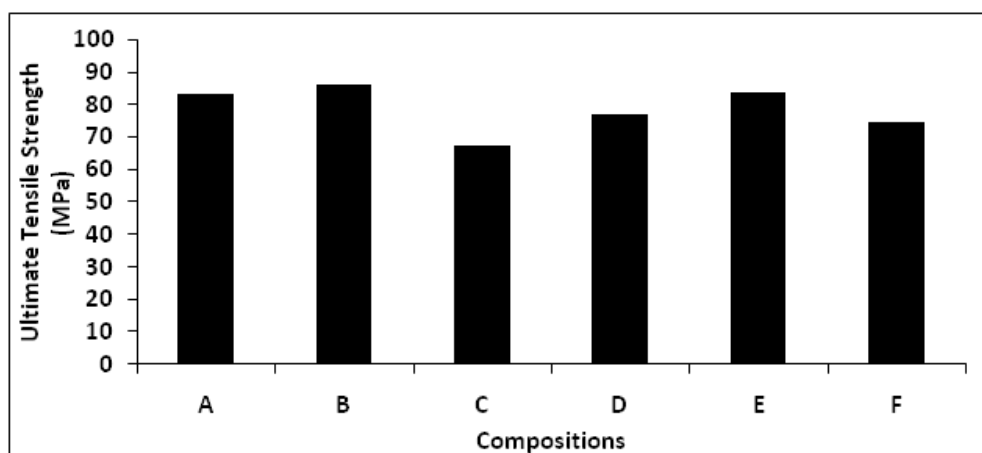
Constituents	SiO <sub>2</sub>	C	CaO	MgO	K <sub>2</sub> O	Fe <sub>2</sub> O <sub>3</sub>	Others
wt%	91.56	4.8	1.5	0.53	0.39	0.21	0.93

### Tensile test

The result of tensile test to determine the ultimate tensile strength, yield strength, strain energy stored, strain to fracture, and fracture toughness of the produced composites are presented in Figure (1–5) respectively.

### Hardness and wear tests

The result of the hardness testing is shown in Figure 6. The variation of the wear resistance obtained is presented in Figure 7 while Figure 8 displays the variation of wear rate of hybrid reinforced Al/BLA-RHA composite.



**Figure 1** Variation of ultimate tensile strength of hybrid reinforced Al/BLA-RHA composite.

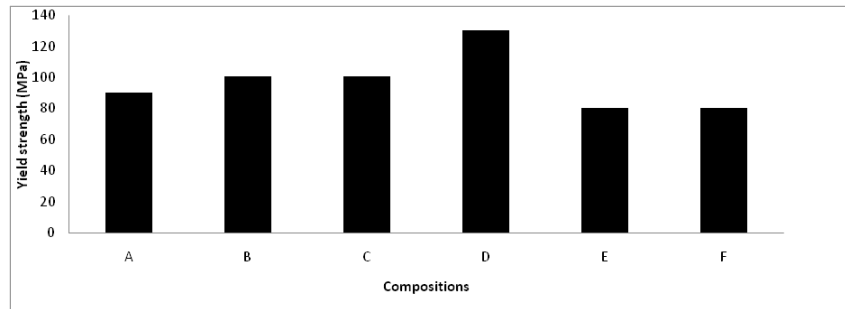


Figure 2 Variation of Yield strength of hybrid reinforced Al/BLA-RHA composite.

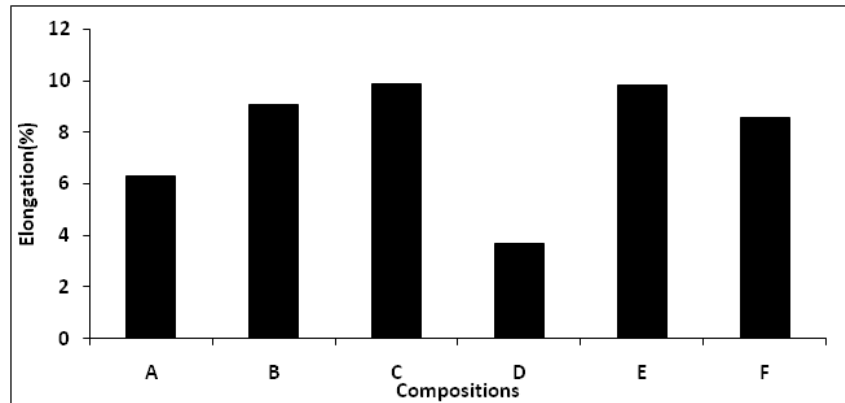


Figure 3 Variation of percentage elongation of hybrid reinforced Al/BLA-RHA composite.

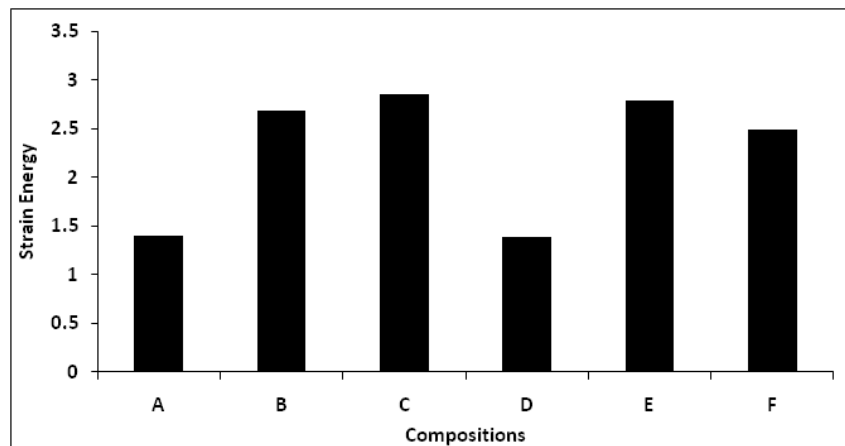


Figure 4 Variation of strain energy of hybrid reinforced Al/BLA-RHA composite.

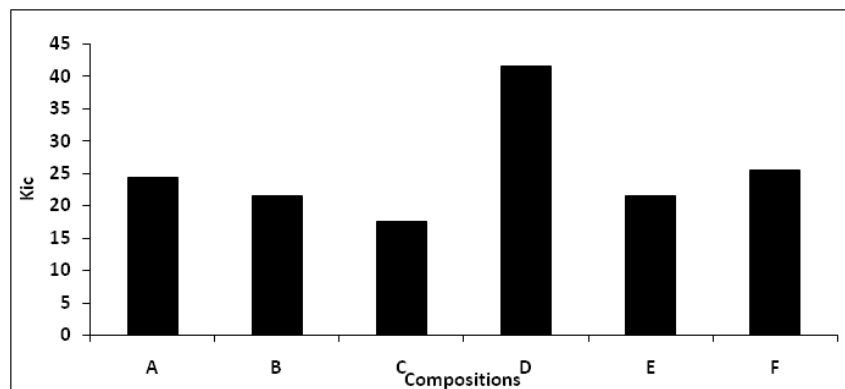


Figure 5 Variation of fracture toughness of hybrid reinforced Al/BLA-RHA composite.

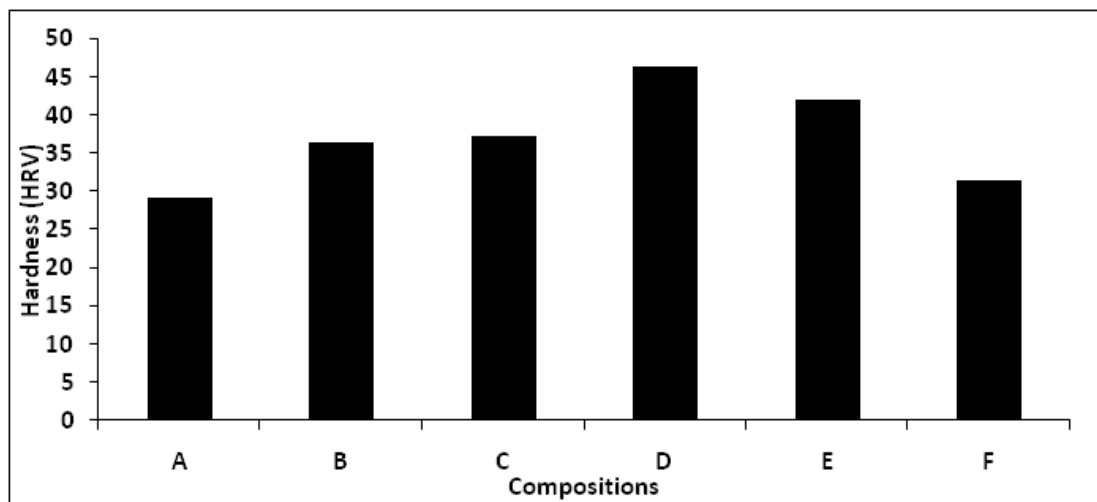


Figure 6 Variation of hardness of hybrid reinforced Al/BLA-RHA composite.

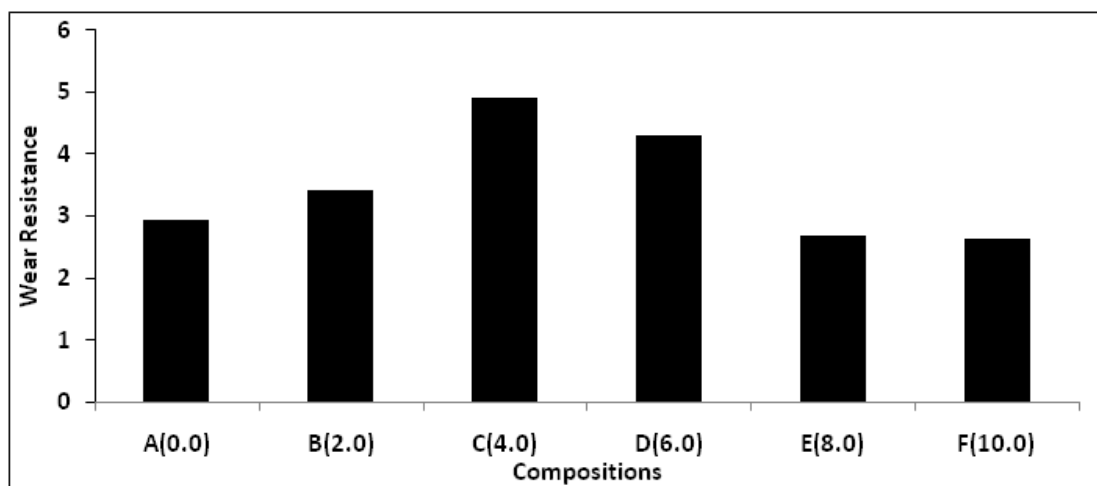


Figure 7 Variation of wear resistance of hybrid reinforced Al/BLA-RHA composite.

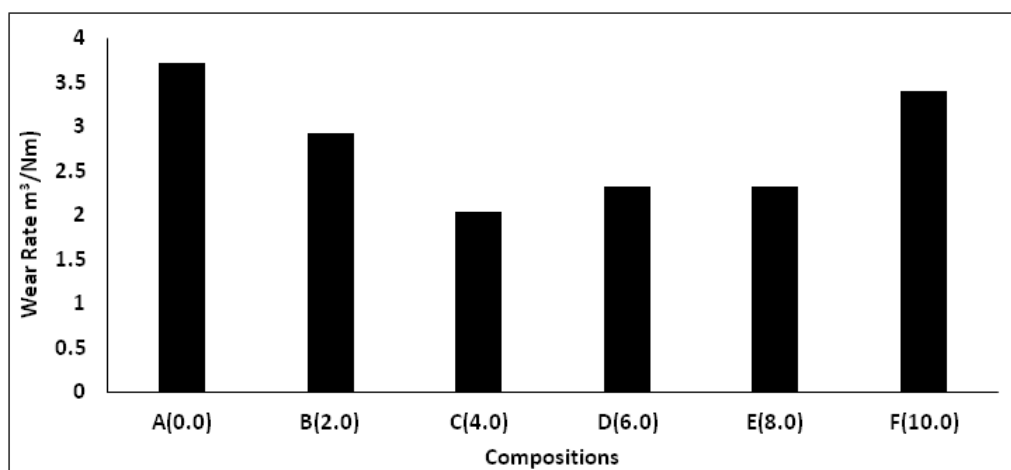
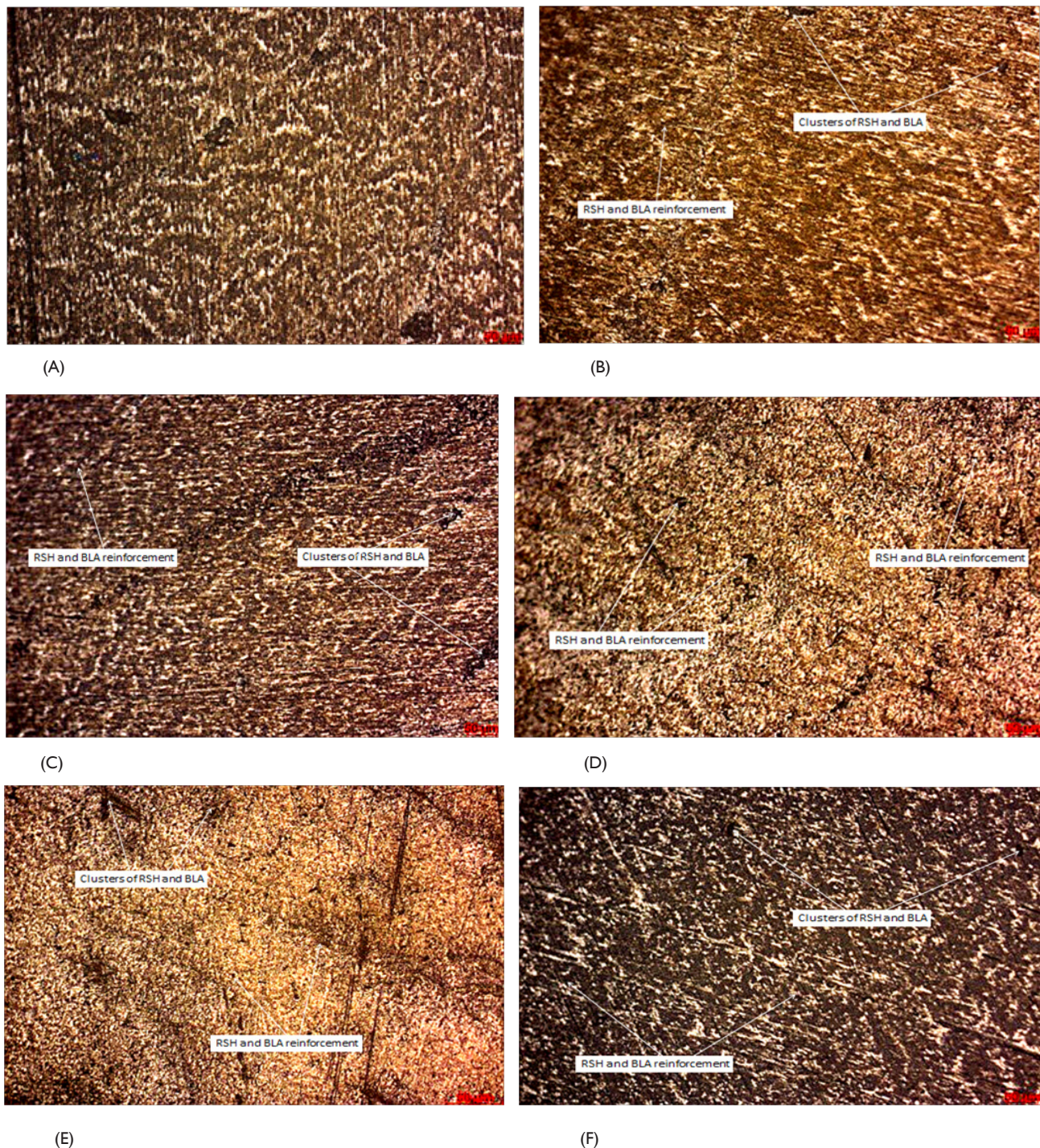


Figure 8 Variation of wear rate of hybrid reinforced Al/BLA-RHA composite.



## Microstructural examination

Figure 9.



**Figure 9** Representative micrographs of composites with 8wt% and 10wt% reinforcement containing BLA:RHA (A)0:1 (B)1:2 (C)1:4 (D)1:6 (E)1:8 (F)1:10.

## Discussion

The ultimate tensile strength of the developed composites - hybrid reinforced Al/BLA-RHA - as observed in Figure 1 shows that 10wt% reinforced composites are superior to that of unreinforced alloy. A maximum UTS value of 135.76 and 136MPa were obtained

for 10wt% composite sample reinforced with 50% BLA and 6wt% composite reinforced with 50% RHA. This implies an increment of 78.4% and 80.0% respectively in comparison with unreinforced alloy. Similar trend is also observed for the yield strength values depicted by Figure 2, the yield strength values of the reinforced composites are superior to that of unreinforced alloy, with 10wt% composite sample



reinforced with 100% BLA and 6wt% composite reinforced with 75% RHA exhibiting the maximum yield strength values of 101.25MPa and 102.2MPa respectively. This also shows an improvement of 78.4% and 80.0% respectively in comparison with unreinforced alloy. The % elongation values in Figure 4 were invariant to the weight ratio of BLA and RHA. A scatter was observed with the % elongation of the composite within the range 10.47%-16.3%. These are within the range reported by literature.<sup>8</sup>

The fracture toughness values in comparison with unreinforced alloy with the exception of samples containing 50% BLA and 50% RHA in 10wt% composite as well as 6wt% composite reinforced with 100% BLA also agrees with the previous work reported by.<sup>8</sup> The variation of micro - hardness values of hybrid composites sample are presented in Figure 6. Among all the composites investigated, 10wt% composites reinforced with 75% BLA and 25% RHA together with 10wt% composites reinforced with equal percentage of BLA and RHA exhibited the highest hardness value of 46.4 and 42.2 respectively. This also implies an increment of 21.7% and 13.4% respectively in comparison with unreinforced alloy. These trends can be attributed to the presence of BLA and RHA in the reinforced composites.<sup>9</sup> Have reported that the basic mechanism of composite deformation is a load transfer from matrix to reinforcement and good bonding between matrix and reinforcement gives rise to better load transfer and improved properties.<sup>10</sup> Also affirmed that in particulate reinforced composites, the load on the matrix gets transferred to the reinforcing elements thereby increasing the load bearing capacity of the composites. With increase in volume fraction of filler material, more loads get transferred to reinforcement which leads to increase in tensile strength. Figure 9 shows the optical microstructures of the Al-BLA/RHA-8wt% and 10% hybrid composite. It was observed that the reinforcing particles (BLA and RHA) are visible and clearly delineated in the microstructure. The particles are fairly well distributed in the Al matrix and signs of particle clusters are minimal. For the microstructural images, partial dispersion of reinforcing particles (BLA and RHA) within the matrix (Al) was observed.

## Conclusion

The mechanical properties of Al (6063) hybrid composites reinforced with Bamboo leaf ash and rice husk ash have been investigated. From the different observations and results obtained from this investigation, it can be concluded that:

- I. The hardness, tensile strength and yield strength of the composites samples were superior to that of unreinforced alloy.
- II. Maximum increase in ultimate tensile strength and yield strength of 78.4% and 80.0% were observed for 10wt% composites sample reinforced with 100% BLA and 6wt% composite sample reinforced with 75% RHA respectively
- III. The % elongation values of composites sample were invariant to the weight ratio of BLA and RHA.

- IV. The fracture toughness values of hybrid composites samples were also found to be superior to that of the unreinforced alloy with the exception of samples containing 75% BLA and 100% BLA in 10wt% composites as well as 6wt% composites reinforced with 100% BLA
- V. From the result obtained BLA and RHA has great potential to serve as complementing reinforcement for the development of low cost-high performance Aluminium hybrid composite.

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## Conflicts of interest

Authors declare that there are no conflicts of interest.

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