Experimental Study of Corn Cob and Cow Horn AA6063 Reinforced Composite for Improved Electrical Conductivity

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Abstract.
Composites are beginning to gain more relevance in numerous areas of engineering applications because of their improved mechanical, physical and electrical properties compared to the parent and indigenous materials. In this study, aluminium matrix composite was developed using aluminium AA6063 as the base material and reinforcement with granulated cow horn and corn cob as organic compounds, in varying percentages of matrix mixture. The particulates, CC, CH and CC-CH were added to the composite in various percentages of 5%, 10%, 15% and 20%. The composite was developed through a stir cast process and further fabricated into a 30mm diameter and 3mm thickness samples. The samples were tested for electrical conductivity and the result showed that the conductivity level of the materials increased to 4.845 x 10^2 S/m compared to the initial conductivity value of 2.947 x 10^2 S/m for the as received aluminium sample.

Keywords; Aluminium matrix composite, Particulate, Electrical Conductivity.

1.0 INTRODUCTION

Composite is basically a word that explains the experimental and scientific combination of minimum of two (2) or more materials together with a goal of improving the properties of the base materials [1]. The materials that make up the composition of composite become optimized and of a better constituent when they are combined together mechanical, physical, electrical, thermal and compositional, but they [2-3].

Aluminium is the thirteenth (13th) element as recorded in the periodic table. It is a metal with a silvery-white colour. An amazing fact about the aluminium material is that it makes up for 8% of the mass of the earth’s core, making it the most widely spread metal on the surface of the earth. Aluminium is invariably about three times less than the weight of iron which makes it one of the very light metals on earth [4]. With the light weight of aluminium notwithstanding, it is still very flexible, strong and possess very high resistance to corrosion because the surface of aluminium is covered with a very thin layer of oxide film. It has no magnetic property; it is a very good conductor of electricity and it is literally capable of forming alloys with several metals [5-6].

Aluminium matrix composite also known as AMC or Aluminum metal matrix composite (AMMC) is universally accepted and utilized engineering materials used for several engineering applications because of their robust potentials as a result of their good mechanical properties and physical properties [7]. Particulates are reinforcements that are added to parent materials like aluminium alloy so as to be able to strengthen the materials, improve the material stiffness,
improve creep properties, wear properties and other related properties compared to the conventional base materials or parent materials of the composite. In the makeup of a composite like metal matrix composite or aluminium matrix composite, reinforcement might be with another metal, organic materials or ceramic compounds [8]. Amongst many others, aluminium metal matrix composites are used in several industries like aerospace. Aircraft, automobile industries and many others. Metal matrix composite that have aluminium of their base material are very effective and efficient when they are used as materials for a brake rotor as compared to matrix alloy and cast iron [9].

In a study [10], aluminium metal matrix composite was fabricated using power metallurgy and stir casting. The developed AMMC contained Graphene, Graphite, Zinc and Magnesium. Several tests were conducted on the developed sample like compression, tensile, and bending for the property characterization of the composite. A microscopic study was carried out on the wear surfaces of the powder metallurgy and cast specimens which had a great impact on the material.

The outcome of a study by [11] shows that there was a significant increase in the electrical resistivity, Young’s modulus and hardness value of cast aluminium base composite that was developed with carbon nanoparticle reinforcement with relative increase in the nanoparticles.

In another study [12], the electrical conductivity and mechanical properties of alumina/zirconia/MWCNT and alumina/MWCNT composite were determined. The use of particulate additive of 1 vol% of alumina/zirconia and MWCNT into composite resulted into a fracture toughness increase by 35% and 8% respectively. In addition, there was an appreciable increase from $10^{-12}$ S/m to $0.27 \times 10^{-2}$ S/m in the value of electrical conductivity for both the base alumina and the composite with MWCNT in 2 vol%.

Since the development of composite has been a very prolific area of research owing to the numerous challenges attached to the applications of engineering materials like aluminium, several attempts have been made to salvage the problem. However, the focus of this experimental study is to evaluate the improved electrical behavior of a developed reinforced composite with the use of agricultural waste as reinforcements and aluminium base material (AA6063).

2.0 EXPERIMENTAL PROCEDURE

2.1. Materials

The base material used for this composite fabrication was aluminium alloy 6063 that was obtained as billets - from Aluminium Rolling Mills in, Ota, Nigeria. The cow horn and corn cobs used as reinforcements were obtained from a nearby farm in Ota, Nigeria. The latter were properly processed and crushed into granulated form. The particulates and the base material were developed into a composite through a stir casting process. The particulate and aluminium alloy mixture were in the following ratios; 0.05:0.95, 0.1:0.9, 0.15:0.85 and 0.2:0.8 for the various particulates and base materials respectively. The mixture of the aluminium base material and the particulates are
shown in table 1 below. Corncob (CC), Cow horn (CH) and a combination of Cow horn & Corncob (CC-CH)

| Sample | Al (vol. %) | Corncob (vol. %) | Cow horn (vol. %) | Corncob + Cow horn (vol. %) |
|--------|-------------|------------------|-------------------|-----------------------------|
| A      | 100         | 0                | 0                 | 0                           |
| B      | 95          | 5                | 5                 | 2.5+2.5                     |
| C      | 90          | 10               | 10                | 5+5                         |
| D      | 85          | 15               | 15                | 7.5+7.5                     |
| E      | 80          | 20               | 20                | 10+10                       |

### 2.2 Experimental Setup and Descriptions

The setup for the electrical conductivity experiment entails a direct current (DC) power supply to channel power to the circuit, a voltmeter to measure the voltage across the connected sample and ammeter to measure the current flow in the circuit (Figure 1).

![Figure 1: Electrical Setup for the Conductivity Test](image-url)
At the commencement of the experiment, the DC power was set to an initial voltage of 0.2v and progressively to 0.4v, 0.6v, 0.8v, 1.0v, 1.2v to 1.4v. The corresponding current and voltage across the samples were taken periodically as the initial commencement voltage increased from 0.2v to 1.4v. The current and voltage values were recorded and used to determine the resistance and to further calculate the resistivity value of the sample by using Equation 1 and 2 respectively.

\[
V = IR \quad \text{(1)}
\]

\[
\rho = \frac{R \times A}{L} \quad \text{(2)}
\]

\[
\sigma = \frac{1}{\rho} \quad \text{(3)}
\]

Where;

V is the voltage
I is the current
R is the resistance
A is the cross-sectional area of the sample
L is the thickness of the sample
\( \rho \) is the electrical resistivity of the sample
\( \sigma \) is the electrical conductivity of the sample

3.0 Results and Discussion

Figures 2-5 shows that the various samples (cow horn reinforced particulate, corncob reinforced particulates, cow horn-corncob matrix reinforcement and the aluminium base control samples respectively), under variations of input voltage behaved differently. The particulates added to the composite had significant effect on the electrical performance of the composite in terms of conductivity. The as-received aluminium sample had a conductivity range of \( 2.947 \times 10^2 \text{Sm}^{-1} \) to \( 3.072 \times 10^2 \text{Sm}^{-1} \) as shown in Figure 5. From Figure 2, it is clear that 200g of cow horn particulate gave the highest conductivity value of \( 4.845 \times 10^2 \text{Sm}^{-1} \). The other particulates also exhibited some level of improvement on the electrical conductivity of the base material. The corncob particulate @200g mixture resulted into \( 4.29 \times 10^2 \text{Sm}^{-1} \) as the peak value from the categories of corncob particulate reinforcement for the composite. However, the mixture of both cow horn and corncob had the least impact on the electrical conductivity level of the developed material with the value of \( 3.263 \times 10^2 \text{Sm}^{-1} \) as reported in Figure 4.
Figure 2; Electrical conductivity of the developed aluminium matrix composite with agricultural waste particulate in varying percentages such as (a) 950g of AA6063 and 50g of Cow horn. (b) 900g of AA6063 and 100g of Cow horn. (c) 850g of AA6063 and 150g of Cow horn and (d) 800g of AA6063 and 200g of Cow horn.
Figure 3: Electrical conductivity of the developed aluminium matrix composite with agricultural waste particulate in varying percentages such as (a) 950g of AA6063 and 50g of corncob. (b) 900g of AA6063 and 100g of corncob. (c) 850g of AA6063 and 150g of corncob and (d) 800g of AA6063 and 200g of corncob.

Figure 4: Electrical conductivity of the developed aluminium matrix composite with agricultural waste particulate in varying percentages such as (a) 950g of AA6063 and 25g of corncob and 25g of cow horn. (b) 900g of AA6063 and 50g of corncob and 50g of cow horn. (c) 850g of AA6063 and 75g of corncob and 75g of cow horn (d) 800g of AA6063 and 100g of corncob and 100g of cow horn.
Conclusion

The completion of this experimental study has proven that the use of biological waste as reinforcement particulates in the development of aluminium composite can enhance the electrical property of the material as it relates to electrical conductivity. The control sample named aluminium alloy 6063 that was used as the basis of comparison for this experiment had an electrical conductivity of 3.072 x 10^{-2} S/m as its peak value at an input voltage value of 1.3v. At the same input voltage, the 200g of cow horn particulate had the highest impact on the conductivity of the material with 4.773 x 10^{-2} S/m. To this end, the use of agricultural waste (cow horn) is hereby recommended for the development of AA6063 aluminium based composite.

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