Effect of Sic Reinforcement on Mechanical And Electrical Properties of Magnesium-Aluminium (Mg-Al) Alloy Matrix Composite

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EFFECT OF SiC REINFORCEMENT ON MECHANICAL AND ELECTRICAL PROPERTIES OF MAGNESIUM - ALUMINIUM (MG-AL) ALLOY MATRIX COMPOSITE

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Abstract
Reinforcing a material with another material or composite formation has become a major technique of material formation. Reinforcement imparts new, and in many cases, improved values of properties on the material being reinforced. In this work an alloy of magnesium and aluminium (magnalium) was reinforced with different weight percentages (2.5, 5, 7.5, 10 wt %) of silicon carbide (SiC) of 600 grit size, making use of stir casting method. The specimens so developed were subjected to various mechanical tests such as hardness, tensile and flexural tests as well as electrical conductivity test. The mechanical properties' tests were conducted using TQ SM1000 Universal Testing Machine using the provision made for each test on the machine while the electrical conductivity test was carried out using an electrical circuit specially designed for the test. It was found out that the samples that were reinforced with SiC had better mechanical properties than the samples that were not reinforced but the conductance values of the reinforced samples were lower than those of samples that were not reinforced. It was also found out that the mechanical properties increased directly proportional to the weight percentage of the SiC particles present in the composite such that the specimen with 10 wt% SiC recorded the highest values of all the mechanical properties that were tested for. For the composite with this wt% reinforcement, the hardness number value was 19.72, tensile strength value, 6328.4 MPa, and flexural strength value, 500.02 MPa but its electrical conductance was 22 S lower than the value of electrical conductance for the sample that was not reinforced at all which was 27.41228 S.

1.0 Introduction
Development of engineering materials with suitable properties for use in specific areas has been one of the major duties of the engineers. In recent days composite formation has become one of the major techniques. of material formation because of the simplicity and functionality of its technicalities [1-3]. There is no single material that possesses all required properties and in sufficient values for every application. For example magnesium has low density and high strength to weight value but does not possess good hardness and tensile strength values. Therefore, it becomes necessary to devise means of imparting the required lacking properties on materials that will make them suitable for some applications. Development of composite materials has been one of the major ways of developing materials with suitable properties for specific applications. Many authors have shown by their investigations, that composite forming leads to improvement of various mechanical properties such as compression and tensile strengths, hardness, corrosion resistance, etc of the material being reinforced [4-8]. Composites are materials made from two or more materials with distinctly different properties but amalgamated and engineered to have specific superior properties different from those of the constituent materials [9,10]. One of the materials will necessarily be in continuous phase known as matrix while the other(s) known as reinforcement will be in non-continuous phase and dispersed. A composite may be made all of metal or all of non-metal or metal and non-metal. Where a metal is the material in continuous phase the composite will be known as metal matrix composite (MMC). In the same vein where any other material is the one in continuous phase, the composite will bear the name of the material, so we have polymer

matrix composite (PMC), ceramic matrix composite (CMC), etc. Magnesium is the ninth most abundant element in the universe and the eighth most abundant element on the earth crust, also the third most commonly used metal following aluminium and iron [11]. Magnesium as an element possesses excellent strength to weight ratio making it a great choice where fuel and power economy is important. Magnesium can help in weight reduction by 70% and 30% if it is used instead of steel and aluminium respectively [12,13]. It has low weight as well as good electrical and mechanical properties making it widely used in manufacturing mobile phones, laptops and tablets computers [14]. Generally speaking, magnesium has excellent ductility, recyclability, thermal conductivity, damping capacity, electromagnetic shielding properties. It also possesses excellent fluidity for casting, low heat capacity, satisfactory heat conduction, good elastic shielding effect, non-magnetic, negative electrochemical potential [15-17].

Magnesium-aluminium alloys, known as magnalium, combine the good properties of aluminium and magnesium. Aluminium in magnesium alloys are known to enhance cast ability and fluidity of the alloys [18]. Aghion et al [19] found in their work that addition of some quantity of aluminium in magnesium alloys improves their cast ability, as well as their tensile, compressive and fatigue strengths. Alloying aluminium with magnesium has been found by some authors to improve its corrosion resistance [20-22]. Magnalium are useful in automobile, aerospace industries because of their light weight and good strength to weight values [14].

Silicon carbide (SiC) is a refractory material with an excellent thermal conductivity and low thermal expansion as such exhibits good thermal shock resistance. It also possesses high hardness value, stiffness and corrosion resistance [23]. In composite production silicon carbide (SiC) has been known as a good reinforcement material. Mg-Al-SiC metal matrix composites combine the outstanding properties of Mg-Al alloys with the exceptional properties of SiC which acts as the reinforcement to give unique properties to the metal matrix composite formed. Md. Rahman et al [24] in their work showed that introducing SiC reinforcement particles in aluminium matrix increases mechanical properties of metal matrix composite. Loto et al [25] found out that SiC made for reduction of corrosion susceptibility of Al-H2S4 while Roland et al [26] in their study showed that SiC addition progressively decreased the corrosion rate and surface morphology deterioration of Mg-Al alloy in the two media. The effect of varying weight percentage addition of this very useful reinforcement agent (i.e SiC) on the mechanical and electrical properties of Mg – Al alloy matrix composite is the focus of this research work.

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2.0 Materials and Method

2.1 Materials

The materials used in this research work include (i) Magnesium (Mg), (ii) aluminium (Al), (iii) Silicon carbide (SiC). These materials were sourced from local market in Nigeria.

2.2 Material Preparation

The different samples of magnesium metal matrix composite for this work were prepared by stir casting method. The metal matrix was made of 62.5 mass % of magnesium and 37.5 mass % of aluminium. Different sets of the composite were produced by adding different mass fraction of SiC to liquid Mg-Al alloy. SiC particles of 600 nm grain size were added in mass fraction of 2.5 %, 5%, 7.5%, and 10% to samples of the Mg-Al metal matrix. The magnesium aluminium (Mg-Al) alloy was melted in a 20 kg diesel fired crucible furnace and the temperature in the furnace was measured using a K – type thermocouple A mass fraction of SiC was added to a melt of Mg-Al alloy and stirred vigorously using a mechanical stirrer to give a required composition of Mg – Al – SiC composite. This was then poured

into a sand mould and left to cool in air. This process was repeated in order to get Mg-Al-SiC composite of different mass fraction of SiC.
After cooling, the various samples so formed were machined to different shapes recommended for various mechanical and electrical tests that they will be taken through. The tests include hardness, tensile strength, impact strength, flexural and electrical conductivity tests.
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2.3 Sample Testing

2.3.1 Hardness Test: This test was carried out on a TQ SM 1000 Universal Testing machine having a steel ball of 10 mm depth indenter. The samples for the test were prepared according to ASTM E10 standard and with a Brinell scale relationship given equation (1) the Brinell hardness values were calculated for the various samples.
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$$HBS = 0.102.\frac{2F}{\pi.D\,(D-\sqrt{(D^2-d^2)}} \quad (1)$$

where HBS =Hardness Brinell Steel, F = Applied force, D = Indenter diameter, d = Indentation diameter

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2.3.2 Tensile Strength Test:
The samples for this test were prepared in accordance with ASTM EBM-91 and the tensile test was conducted on Universal Testing Machine – UTM (Instron5567). A test sample was gripped at both ends and the machine slowly pulls the sample until it fractured.

2.3.3 Flexural Test:
To investigate the flexural strength of the composite samples, they were subjected to three-point bending test using an Instron-series 3369 Universal Testing Machine. The samples for the test was prepared according to ASTM D 790M standard.

2.3.4 Electrical Conductance Test:
For conductance determination a simple model circuit as shown in figure 2.1 was used. The target was to determine the voltage and current across each of the samples as the voltage in the circuit was varied from 0.2V to 2V. From these values the resistance, resistivity and conductance of each sample were calculated using the standard relationship shown below:

$$R = V/I \quad (2)$$

where V = voltage and I = current

$$\boldsymbol{\rho} = RAl \quad (3)$$

where **ρ** = resistivity, A = area and l = length

$$C = 1/\rho$$

where C = conductance

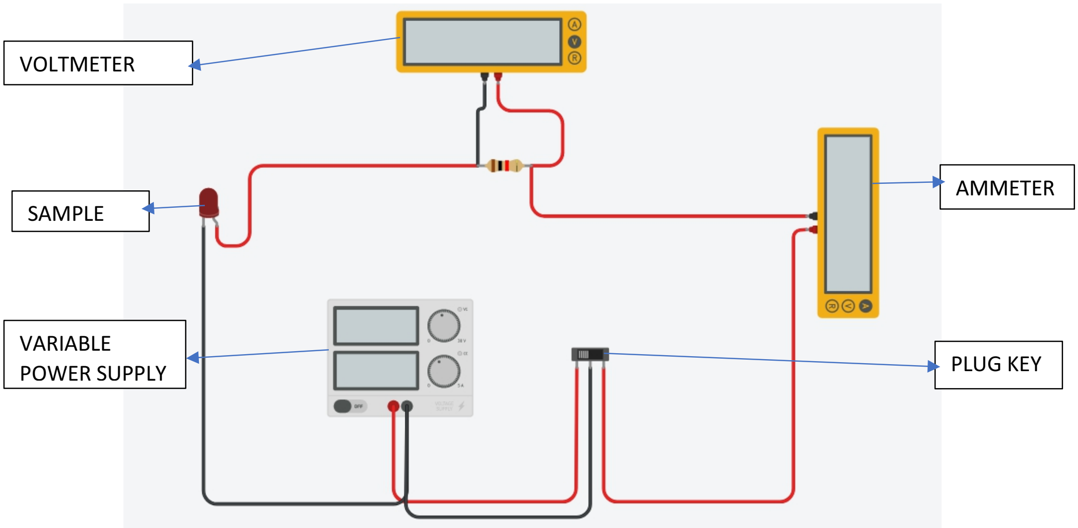

Figure 1: Model Circuit for Resistance Determination Drawn on Tinker CAD.

3.0 Result and Discussion

3.1 Brinell Hardness

The variation of Brinell hardness of the Mg-Al-SiC composite with the wt % of SiC reinforcement in the Mg-Al matrix is shown in Figure 2. This graph shows greater hardness value in the composites than in the Mg-Al alloy without SiC. It also shows that the hardness increases as the wt % of SiC increases. The composite with 2.5% wt of SiC recorded hardness of 10.34 Hv greater than Mg-Al alloy without SiC reinforcement which recorded hardness value of 9.72 Hv. It can also be observed that the Mg-Al-SiC composite with 10% wt of SiC reinforcement records 19.72 Hv while the one with 2.5% wt of SiC has hardness value of 10.34 Hv as stated earlier on.. This can be attributed to the presence of the harder particles of SiC and also to the fact that the SiC particles are well bonded to the Mg-Al matrix thereby obstructing the movement of dislocations in the matrix and the more the presence of this particles the better the dislocations are obstructed leading to better hardness.

3.2 Tensile Strength

Figure 3.2 shows the graph of variation of tensile strength with wt % of SiC in the composite. The graph shows that increase in wt% of SiC in the composite leads to improvement of tensile strength. The graph also shows the tensile strengths of the samples increase as the wt% of SiC increases in the composite. It can be seen from the graph that the tensile strength in the sample that doesnot contain SiC is less than that of the sample that has least amount of SiC in it. The increase in the tensile strength in the samples with SiC reinforcement can be attributed to the applied tensile load transfer which is as a result of the strongly bonded SiC reinforcement to the Mg-Al matrix, strengthening effect from grain refining, and rise in dislocation density near matrix/reinforcement interface. Increase in wt.% of SiC, leads to increase in those factors that promote tensile strength and thus make for increase in tensile strengthe. The sample having 10.0 wt. % of reinforcement has a tensile value of 6328.4 N being the highest in this study.

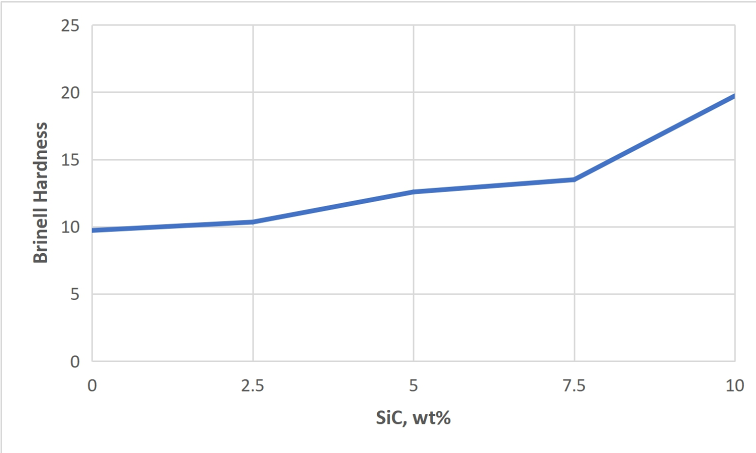

Figure 2: Graph of Variation of Brinell hardness With Wt. % of Sic in MMC

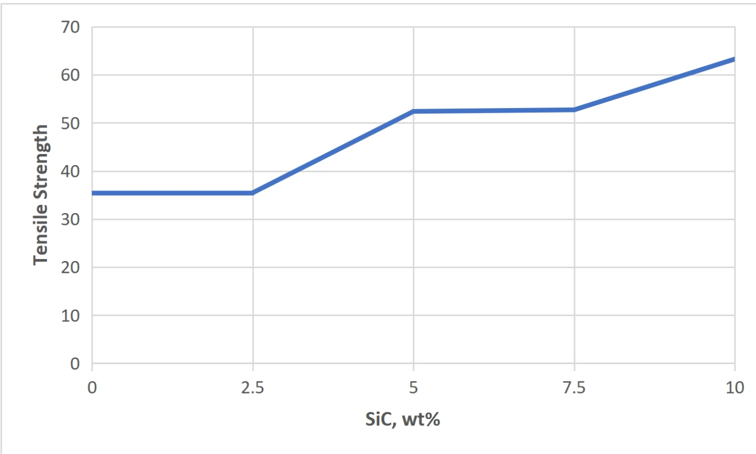

Figure 3: Graph of Tensile Strength against wt% of SiC.

3.3 Flexural Strength

The graph of variation of flexural strength against wt% of SiC in the Mg-Al alloy metal matrix composite in this study is given in Figure 4. As seen for other mechanical properties considered before the flexural strength values also increases as the wt5 of SiC increases in the composite with the value in the control sample ie the sample without SiC being smaller than that of the sample that contains the least wt% of SiC. The enhancement of flexural strength values of samples that have SiC is due to the presence of a high percentage of SiC content that acts as barriers to cracks instigated at the matrix/particle interface.

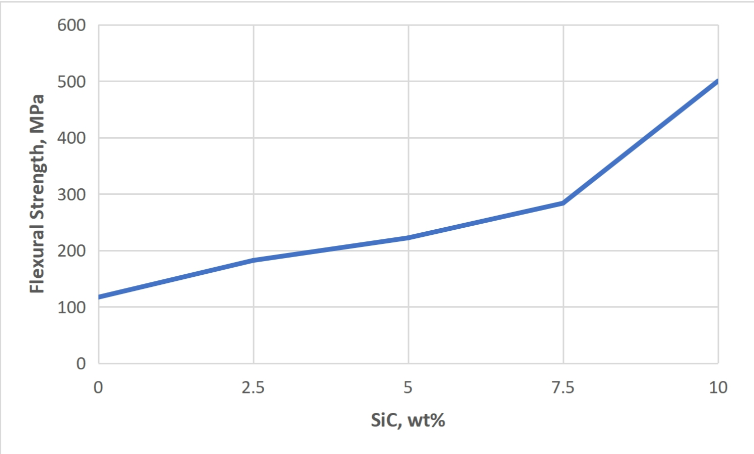

Figure 4: Graph of Flexural Strength against wt% of SiC

3.4 Electrical Conductance

Table 1 shows how current, voltage, resistivity and conductance vary with wt% of SiC in the composite under study while Figure 4 gives the variation of Electrical conductance of the composite with the wt% of SiC in it.

Table 1: Current, Voltage, Resistivity and Conductance of Samples

SiC (wt%)	Current (A)	Voltage (V)	Resistivity Ωm	Conductance S
0	2.045	0.523	0.03648	**27.41228**
2.5	2.117	0.633	0.04261	**23.46867**
5.0	2.149	0.654	0.04332	**23.08408**
7.5	2.162	0.659	0.04346	**23.00966**
10	2.165	0.664	0.04375	**22.85714**

The graph reveals that the conductance of the composite decreases as the wt% of SiC increases and that the Conductance of Mg-Al alloy without SiC reinforcement is greater than that of any of the composite (which contains SiC reinforcement). These can be explained by fact that particles of SiC, a semi-conductor, dispersed in the matrix of Mg-Al alloy impede the flow of electricity through the later. The more the semi-conductor in the composite the more the impedance to flow of electricity and therefore the less the conductance of the material.

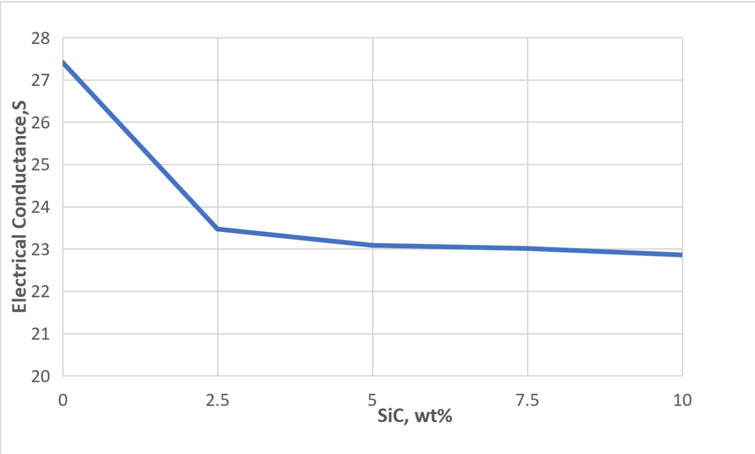

Figure 5: Graph of Electrical Conductance against wt% of SiC

4. Conclusion

In this study different samples of Mg-Al alloy metal matrix composite reinforced with SiC were produced, using stir casting method, by varying the weight % of the SiC in the metal matrix. Each sample of this developed composite was subjected to mechanical and electrical properties tests as hardness test, tensile test, flexural test and electrical conductance test. The following conlusion can be drawn from this study:

- The Mg-Al alloy metal matrix composite reinforced with SiC possesses superior mechanical properties of hardness, tensile strength and flexural strength compared to unreinforced Mg-Al alloy.
- The values of those mechanical properties increase as the wt% of the SiC reinforcement increases in the composite.
- On the other hand, the electrical conductance of the Mg-Al alloy is greater than the electrical conductance of Mg-Al matrix composite reinforced with SiC.
- The electrical conductance of the Mg-Al matrix composite reduces as the wt% of SiC increases in it.

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