Effects of Silicon Carbide (SIC) Nano Particulates Addition on Mechanical Properties of Aa2618 Alloy

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Abstract- This work investigated the effects of addition of silicon carbide (SiC) as nano particulate reinforcement material on the mechanical properties of AA2618 alloy. The experiment was conducted by adding varying weight percentage fractions of silicon carbide (SiC) nano particles: 5%, 10%, 15%, 20%, 25% and 30%, to molten AA2618 alloy via compocasting route. On solidification, the samples were machined and mechanical properties test such as hardness, ultimate tensile strength, density; Young's modulus and yield strength were carried out. The results indicated that the developed method was quite successful to obtain uniform dispersion of particle reinforcement material in the matrix of the alloy. The hardness, ultimate tensile strength, density, Young's modulus and yield strength were found to increase as the percentage of silicon cabide (SiC) reinforcement particles increased except for ductility that decreased with increase in the percentage of reinforcement particles. Therefore nano silicon carbide (SiC) particles were found to be good reinforcement material for AA2618 alloy composite.

Index Terms- Reinforcement, Matrix, Ultimate Tensile Strength (UTS) Dispersion, AA2618.

I. INTRODUCTION

AA2618 is an age-hardenable cast aluminum alloy. It has good corrosion resistance against mild alkaline and salt spray exposure, which makes it well suited for automotive and military applications [1]. It also has good dimensional stability at relatively high temperature and this makes it a good material for use in welding structure [2, 3].

Despite all these qualities, its mechanical properties needed to be enhanced for better engineering applications. To achieve this, the alloy needs to be reinforced with ceramic material to improve on some of its mechanical properties.

Metal matrix composite (MMC) is engineered combination of the metal (matrix) and hard particle ceramic reinforcement to get tailored properties. MMC's are either in use or prototyping for the space shuttle, commercial airliners, electronic; substrate, bicycles, automobiles, golf clubs, and a variety of other applications. [4]

Like all composites, aluminum matrix composite are not a single material but a family of materials whose stiffness, strength density, thermal and electrical properties can be tailored. The matrix alloy, reinforcement material, volume and shape of the reinforcement and fabrication method can all be varied to achieve required properties. Among discontinuous metal matrix composites, stir casting/compocasting is generally accepted as a promising route, currently practiced commercially. Its advantage lies in its simplicity, flexibility and applicability to large quantity production. It is also attractive because in principle, it allows a conventional metal processing route to be used, and has minimizes the final cost of the product [4]. The aim of designing metal matrix composite materials is to combine the desirable attributes of metals and ceramics. The addition of high strength, high modulus refractory particles to a ductile metal matrix produce a material whose mechanical properties are intermediate between the matrix alloy and the ceramic reinforcement [5]. Metals have a useful combination of properties such as high strength, ductility and high temperature resistance, but sometimes have low stiffness, whereas ceramics are stiff and strong, though brittle. Aluminium and silicon carbide, for example, have different mechanical properties. Young's moduli of 70 and 400 GPa, coefficients of thermal expansion of 24 x 10^{-6} and 4 x $10^{-6}/^{0}C$, and yield strengths of 35 and 600 MPa, respectively. By combining these materials, e.g. A6061/SiC/17p (T6 condition), an MMC with a Young's modulus of 96.6 GPa and yield strength of 510 MPa can be produced [6]. By carefully controlling the relative amount and distribution of the ingredients of a composite as well as the processing conditions, these properties can be further improved. Therefore, this work is aimed to fabricate and study the mechanical properties of AA2618 alloy reinforced with various weight percentages of silicon carbide (SiC) nano particles.

II. EXPERIMENTAL WORK

The raw materials used in this work were aluminum AA2618 ingot, distilled water, silicon carbide (SiC) powder, charcoal and table salt. They were got from Enugu State University of Science and Technology, Department of Metallurgical and Materials Engineering Laboratory. High temperature electric graphite crucible furnace ($1300^{0}C$) heat

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generation efficiency was used to melt the aluminum alloy scrap. The chemical composition of the aluminum alloy produced is as shown in table 1.

Table 1: Chemical compositions of Aluminum AA2618 alloy.

Elements	*Cu*	*Fe*	*Si*	*Ti*	*Mg*	*Mn*	*Zn*	*Ni*	*Al*
% composition	*2.5*	*0.91*	*0.15*	*0.05*	*1.5*	*0.20*	*0.1*	*0.11*	*Balance*

In other to produce the composite, the molten aluminum alloy was de-slaged and de-gased, and thereafter, different weight percentages of silicon carbide (SiC) particles, (5%, 10%, 15%, 20%, 25% and 30%) were added to a constant volume of molten aluminum alloy at a temperature of 750^0C through compocasting method, and was stirred using mechanical stirrer for uniform distribution of the particles within the melt. It was allowed to stay for 45 minutes at a constant temperature of 700^0C. Finally the melt was cast into already prepared and preheated permanent moulds. After solidification, the samples were removed, machined and prepared for different mechanical tests.

III. RESULTS AND DISCUSSION

Table 2: Mechanical properties of AA2618 alloy & AA2618/SiC composites.

	Ductility (%EL)	Yield Strength (MPa)	Ultimate Tensile Strength (MPa)	Young's Modulus E(GPa)	Hardness (BHN)	Density (g/cm^3)
AA2618 + 0 wt% SiC	16.40	208	240	74.0	67.0	2.713
AA2618 + 5 wt% SiC	7.41	220	248	86.1	81.3	2.784
AA2618 + 10 wt% SiC	6.48	231	264	87.8	83.1	2.826
AA2618 + 15 wt% SiC	5.22	242	285	89.7	88.3	2.901
AA2618 + 20 wt% SiC	4.73	253	298	94.4	89.1	2.982
AA2618 + 25 wt% SiC	3.11	264	318	96.3	90.3	3.214
AA2618 + 30 wt% SiC	2.70	259	301	91.6	87.2	3.110

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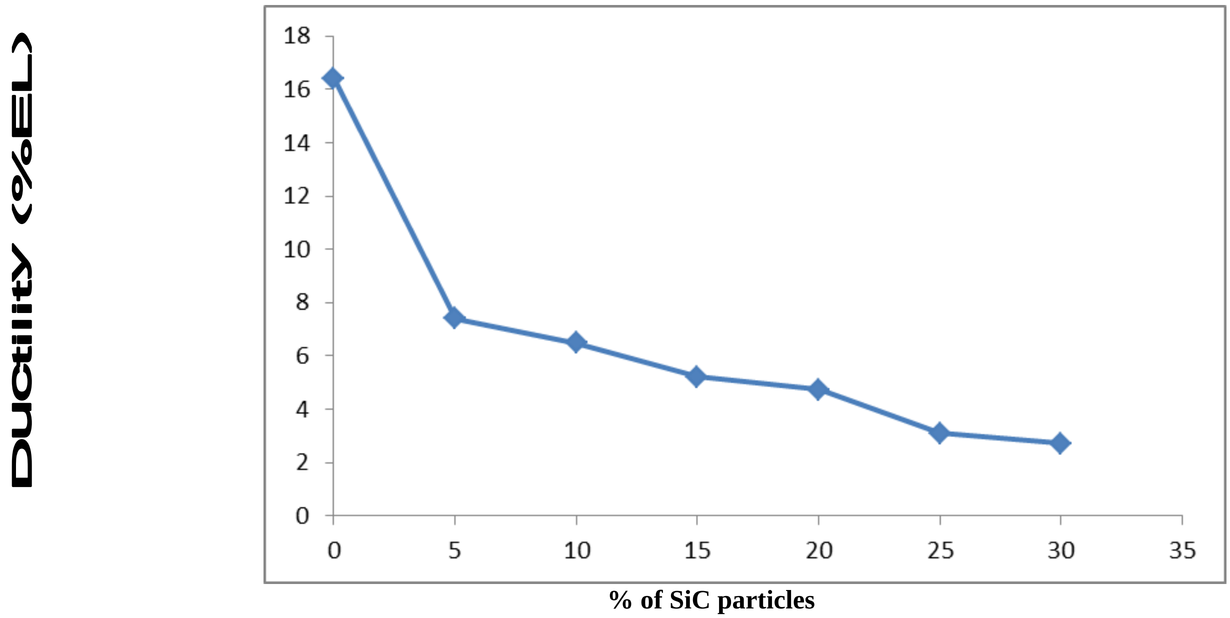

Figure 1: *Effect of wt% of silicon carbide nano particles addition on ductility of AA2618/SiC composite.*

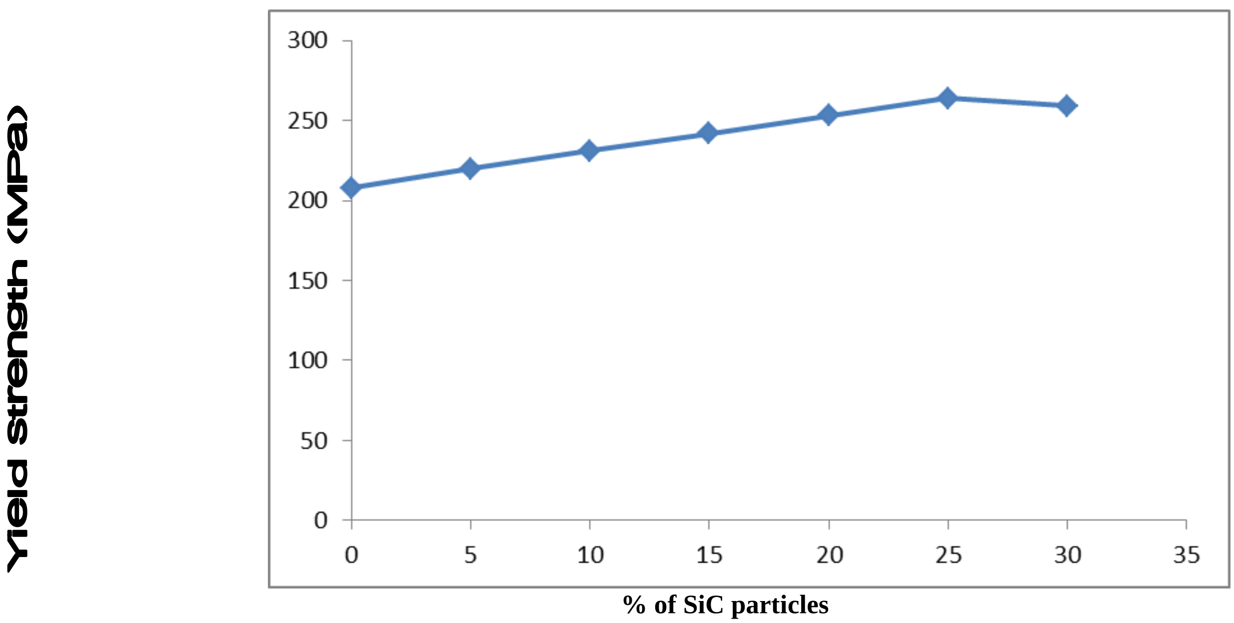

Figure 2: *Effect of wt% of silicon carbide nano particles addition on Yield strength of AA2618/SiC composite.*

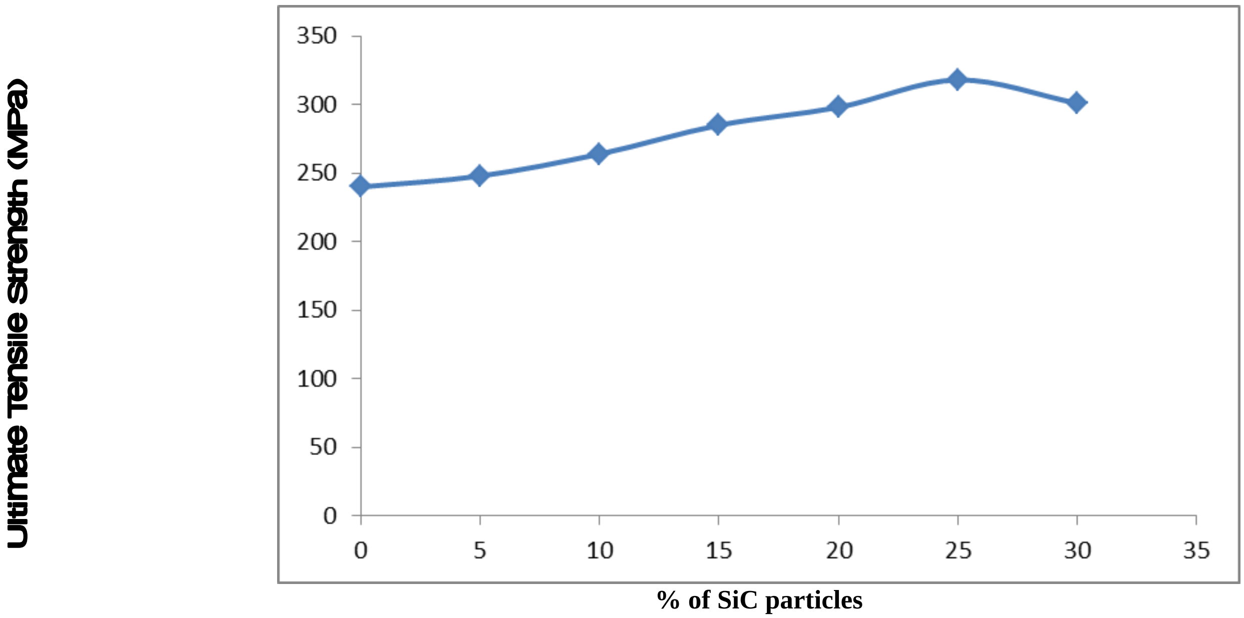

Figure 3: *Effect of wt% of silicon carbide nano particles addition on Ultimate Tensile Strength of AA2618/SiC composite.*

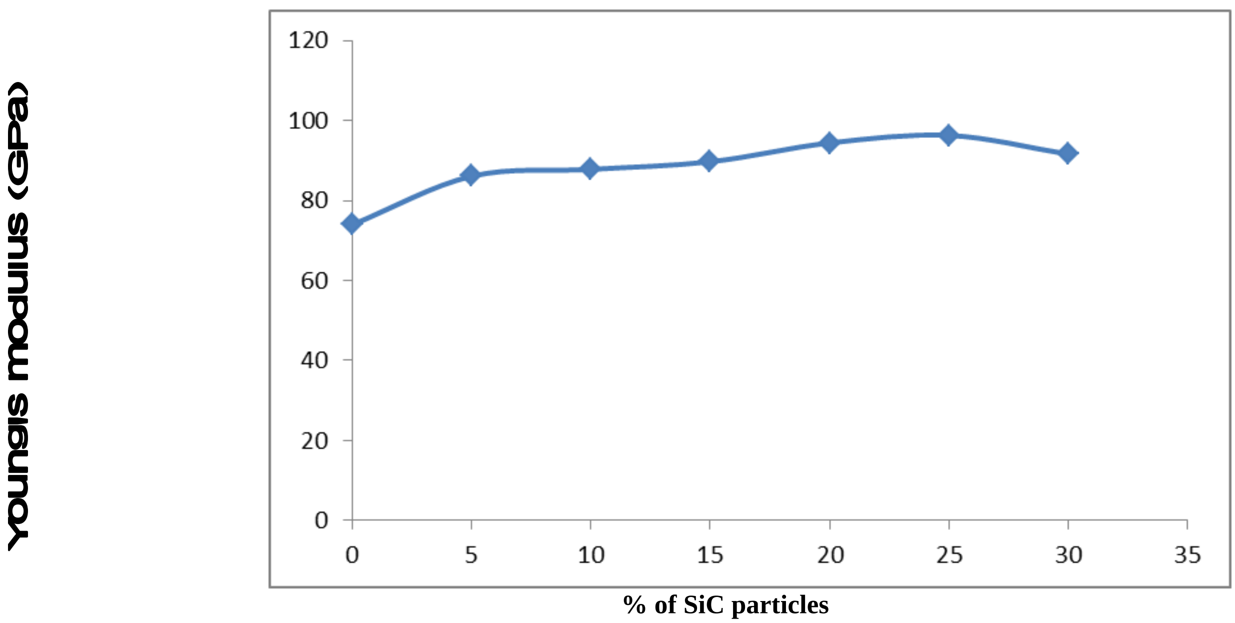

Figure 4*: Effect of wt% of silicon carbide nano particles additionon Young's modulus of AA2618/SiC composite.*

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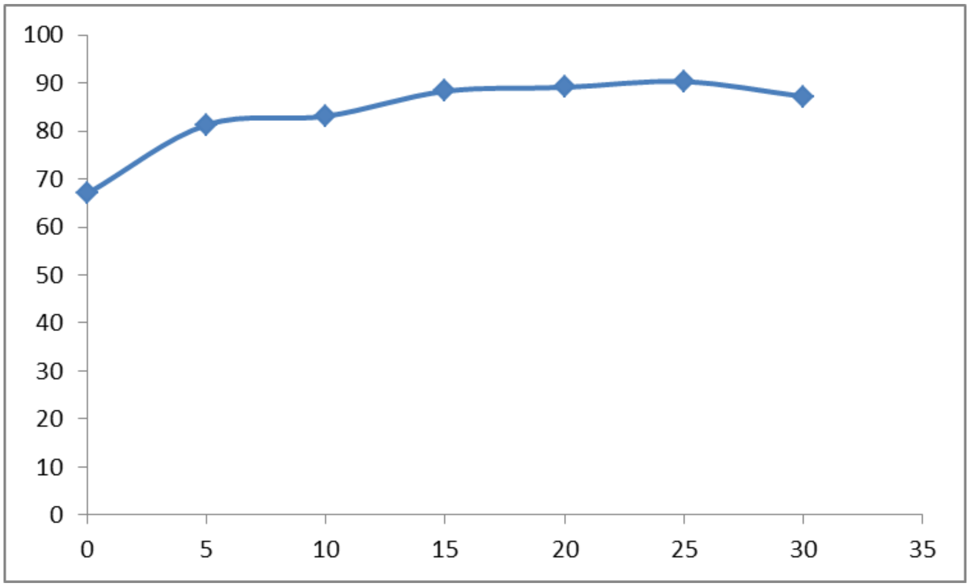
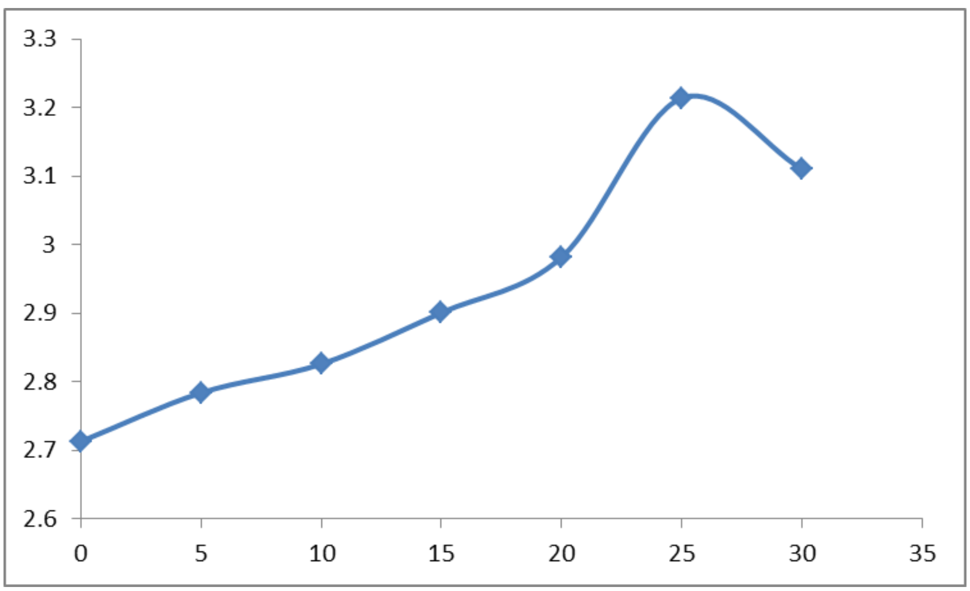


% of SiC particles

Figure 5: *Effect of wt% of silicon carbide nano particles addition on Hardness of AA2618/SiC composite.*

Density (g/cm3)
Hardness (BHN)



% of SiC particles

Figure 6*: Effect of wt% of silicon carbide nano particles addition on density of AA2618/SiC composite.*

The formation of reinforced AA2618 ceramics composites containing different percentages of SiC particles addition were carried out by compocasing route. The results of the mechanical properties of the materials tested are summarized in Table 2 and also presented in graphical forms in Figures 1-6. Figure 1 represents the effect of SiC addition on the ductility of the composite. A clear look at the graph shows that increase in the weight percentage addition of the reinforcement particles decreases the ductility of the composite material. This implies that there is a remarkable decrease in the percentage elongation of the composite due to addition of reinforcement material. The reason to this could be attributed to brittle and hard nature of SiC particles. Since SiC is a refractory material with high brittleness, when dispersed in matrix of the aluminum alloy it filled the pores and displays its brittle nature. This therefore decreases the ductility of the composites.

Furthermore, addition of SiC particles to the aluminum alloy results in increased yield strength, ultimate tensile strength, Young's modulus, hardness and density as shown in Figures 2, 3, 4, 5 and 6 respectively. Figure 6 which is the graph of effect of SiC addition on the density of the composites clearly showed that reinforcement particles which are smaller than the matrix particles situate themselves in between the matrix particles and fill the pores. This caused an increase in the density of the composites when compared with the AA2618 alloy. Figure 2, 3, 4 and 5 showed increase in yield stress, ultimate tensile strength, Young's modulus and hardness respectively, with the increasing quantity of SiC particles up to a critical reinforcement concentration. This behavior is as a result of high mechanical properties of SiC which include relatively high yield strength, high Young's modulus, etc except its ductility that is very poor. It is then expected that these features will contribute positively on the mechanical properties of AA2618/SiC composites when SiC particles are uniformly dispersed as a reinforcement material. However, there is an actual SiC particles percentage addition, through which the maximum values of these mechanical properties decrease. This value corresponds to 25% nano particles addition. Beyond this value, SiC clusters form in the composites and these clusters deteriorate the mechanical properties of the composites by lowering its values as can be seen in the graphs of Figures 2, 3 and 4.

Therefore, when we look at the data for the composites reinforced with SiC particles, of less than or equal to 25% nano particle addition leads to the conclusion that such value provides a higher increase of the ultimate tensile strength, Young's modulus, yield strength and hardness where as the composites containing more than the value deteriorate its mechanical properties as a result of SiC clusters formed in the composites.
Finally it is deduced that SiC of a nano size is a good reinforcement to AA2618 alloy since it increased the mechanical properties of the alloy except the ductility which is given out as a result of increased in hardness as shown in Figure 1. These improvements are consequence of uniform dispersion of SiC particles in the matrix of the alloy.

IV. CONCLUSION

From the results of the study discussed above, the following conclusions can be made.

1. A fine and uniform particle distribution of SiC increased the yield strength, ultimate tensile strength, Young's modulus, density and hardness of the alloy
2. Addition of SiC particles decreased the ductility of the composites
3. Uniform distributions of the nano particles within the composites enhanced material fabrication.
4. Addition of nano SiC particles above a critical value within the composites lowers the mechanical properties of the composite. This is because of the formation of SiC clusters.

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