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DEVELOPMENT AND CHARACTERISATION OF RECYCLED ALUMINUM SILICON CARBIDE COMPOSITES

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ABSTRACT

This study was conducted to develop a composite using recycled aluminum Cans matrix and silicon carbide particulates as the reinforcement material. Various compositions were developed using recycled aluminum cans matrix and 0, 2, 4, 6, 8 and 10% weight of silicon carbide particles through stir casting method. The composites were stirred at two temperatures 700ºC and 750ºC while other processing parameters (Stirring time, stirring speed and pouring temperature) were kept constant. The mechanical properties (ultimate tensile strength, compression strength, impact strength, flexural strength and hardness) and physical properties (density) were determined for the developed composite. The results obtained revealed that density reduced with increase in additions of silicon carbide contents in the composites while compressive strength was generally decreased as the reinforcement increases. The results also revealed that addition of silicon carbide in the composites increase the tensile strength, impact strength, flexural strength and hardness by 90%, 119%, 53%, and 61% respectively over that of unreinforced matrix. Composite stirred at 750ºC have better properties when compared to composites stirred at 700ºC. Conclusively, the properties of recycled aluminum cans matrix can be improved with SiC particle reinforcement for engineering applications such as sprocket, break pad, e.t.c.

Keywords: *Recycle, Matrix, Reinforcement, Composite, Silicon Carbide.*

1. INTRODUCTION

In recent times composite materials have been the foremost emerging materials in the engineering industry. The volume of applications of composite materials in the engineering industry has increased steadily over the years and is penetrating and conquering new markets significantly. Composites are compound materials which differ from the alloys by the fact that the individual components retain their characteristics but incorporated in the composite so as to take advantage only of their attributes and not of their shortcomings, in order to obtain an improved material [1].

Unlike alloys, composites must be a combination of at least two chemically distinct materials with a distinct interface separating the constituent materials [2]. According to matrix constituent, composite are classified into organic matrix composites, metal matrix composites (MMCs) and ceramics matrix composite. Among these composites, MMCs provide significantly enhanced properties such as higher strength at elevated temperature, high specific modulus and high damping capacity. The reinforcement material may be subdivided into four major categories which are; continuous fibre, Short fibre, whisker and particulate.

Metal matrix composites are relatively new range of advanced materials providing properties that may not be achieved by conventional materials. The benefit of MMCs is that they can be tailored to produce various combinations of properties (weight to strength ratio, enhanced modulus, high hardness, enhancement of corrosion resistance, thermal shock resistance at higher temperature etc.) [3]. MMCs materials have a combination of diverse, superior properties compared

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to an unreinforced matrix, these can result in various service benefits, among which include increased strength, better fatigue resistance, high elastic modulus, improved wear resistance, higher service temperature, decreased part weight, high toughness and impact properties, high electrical and thermal conductivity and low coefficient of thermal expansion [4] and [5].

Some researchers have studied different aluminum matrix composite through various fabrication techniques and using different ceramic particles reinforcement ($\mathrm{Al_2O_3}$, SiC, TiC, fly ash, etc). A research [6] was conducted to study the wear behaviour of hybrid aluminum (Al) metal matrix reinforced with silicon carbide (SiC) and aluminum oxide ($\mathrm{Al_2O_3}$) through sintering technique. It was observed that, wear resistance increases with increase in content of reinforcement in the matrix while composite reinforced with SiC=[have better wear resistance when compared to composite developed with $\mathrm{Al_2O_3}$ particle as reinforcement. In [7], a research conducted to study the properties of aluminum metal matrix reinforced with fly ash particulate in varying proportions 5, 10, 15, and 20 wt% of fly ash processed by stir casting method. The result shows that hardness increase as the fly ash percentage increases in the matrix while tensile strength decreases at the higher content of fly ash particle in the composite. In this research [8], two different types of particles (SiC & $\mathrm{Al_2O_3}$) were used to reinforced the aluminium matrix at varied weights percentage (5, 10, 15 wt%), the composite reinforced with SiC have better physical and mechanical properties.

In a similar research [9], a composite was developed and Characterised using Al-Cu-Mg as matrix and TiC particulate (in varying proportions 1wt% TiC, 2 wt% TiC and 3 wt% TiC) as reinforcement through stir casting technique. Hardness test result shows an increment of about 7% compared to base metal. Tensile test result (yield stress, ultimate tensile strength and percentage elongation) revealed a great improvement while density increases with increase in content of TiC in the composites.

Properties of Al-SiC metal matrix composites have been widely studied [1, 3, 10 – 15] and generally observed that, the Al – SiC composite material can offer several advantages such as; The friction coefficient of Al-SiC MMC is 25-30% time that of cast iron and have better wear characteristic than cast iron or steel, the thermal conductivity of Al-SiC MMC can be two to three times higher than cast iron, the Al-SiC pads/lining could be 60% lighter than that of cast iron. The objectives of this study is to develop recycled aluminum metal matrix composite reinforced with Silicon Carbide particles of various compositions by stir casting method and to determine the influence of reinforcement (SiC) particle variation on the mechanical properties and microstructures of the composites.

2. MATERIALS AND METHODS

In this section the various materials and equipment used to conduct the work are presented.

2.1 Materials and Equipment

The materials used in this study are aluminum cans scrap (recycled) which were sourced from Kano metropolitan hotels/restaurants in Nigeria, while silicon carbide (18 μm) was obtained from National Metallurgical Development Centre, Jos, Nigeria. The equipment employed in this study are: mechanical stirrer, crucible, electrical resistance furnace, pyrometer, digital weighing balance, Lathe machine, molding box, silica sand, Universal hardness tester IDENTEC 8187.5 LKv(B), universal testing machine Cussons P5030, a pendulum type impact test machine and scanning electron microscope machine. Other equipment used are, files, masking tape, arc saw, pencil and grit paper of various sizes 120, 240, 320, 400 and 600.

2.2 Methods

2.2.1 Processing of aluminum cans scrap.

Aluminum cans scrap was first collected and separated from Kano metropolitan hotels and restaurants. The cans were crushed into small sized pieces to lessen the volume and also make it easier for cleaning and removal of impurity. The small sized pieces were then loaded into the furnace and heated above melting point (630°C) temperature to produce molten aluminum. The molten aluminum was poured into the mold for solidification and small sample was taken for chemical analysis (XRF) using X-ray spectrometer.

2.2.2 Fabrication of Recycled Aluminum Matrix composite (RAMC) samples

The recycled aluminum metal matrix composite was produced by using double stir-casting method. The composites were produced by varying the percentage of Silicon carbide particle between 0 to10 wt% (0, 2, 4, 6, 8 and 10) at 700°C and 750°C stirring temperature each while keeping other processing parameters (stirring time, stirring speed, pouring temperature etc.) constant. The Silicon carbide particles were preheated in the furnace (1000°C for one hour) to make its surface Oxidised for promotion of wettability. The molten matrix was then cooled to temperature just below the melting point to keep the slurry in a semi-solid state. At this stage the preheated SiC particles was added and mixed manually. After manual mixing, the composite slurry was re-heated to temperatures of 700°C and 750°C respectively. Then automatic mechanical mixing was introduced for about 3 minutes at an average stirring speed of 200 rpm

3. RESULTS AND DISCUSSION

3.1 Result

The results of the mechanical, physical tests and microscopy conducted to determine the properties of the developed composites of various compositions are presented in this section.

Table 3.1 Chemical Composition of Recycled Aluminum cans matrix

Element	Weight %
Al	96.40
Cl	0.45
Ca	0.097
Ti	0.0095
V	0.12
Cr	0.016
Mn	0.98
Fe	0.95
Ni	0.070673
Cu	0.321
Zn	0.127
Ga	0.0054
As	0.001
Sb	0.03
La	0.11
Pr	0.180
Ti	0.085375
Pb	0.047

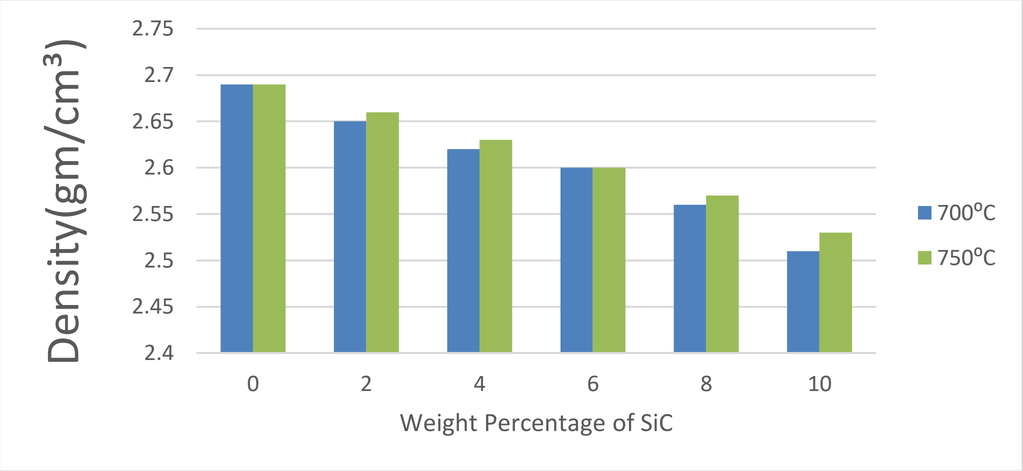

Figure 3.1. Variation of density with wt% *of silicon carbide particles*

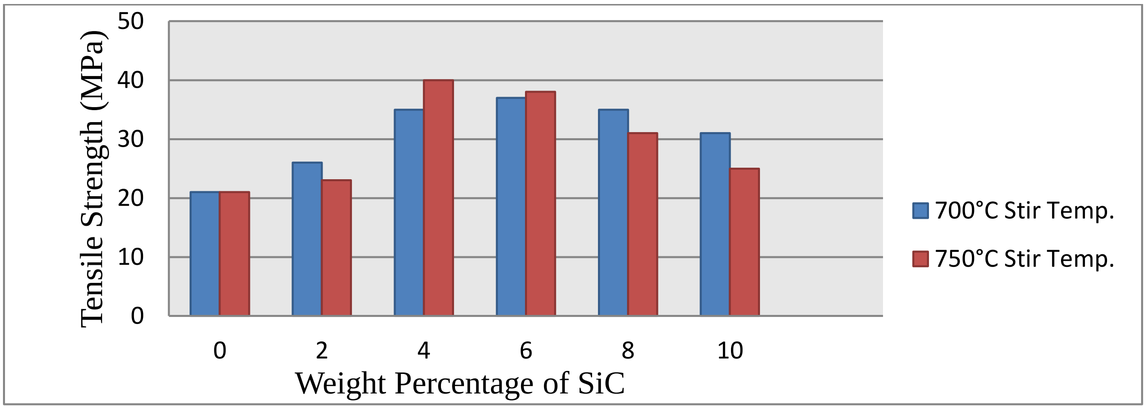

Figure 3.2 Variation of tensile strength with wt% *of silicon carbide particles*

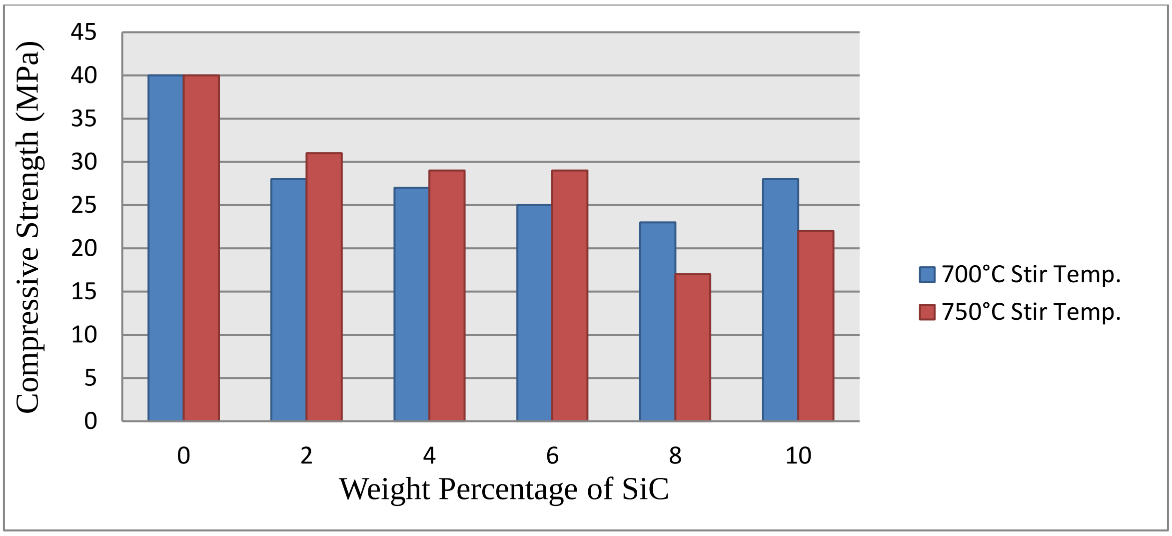

Figure3.3 Variation in compressive strength with wt *% of silicon carbide particles*

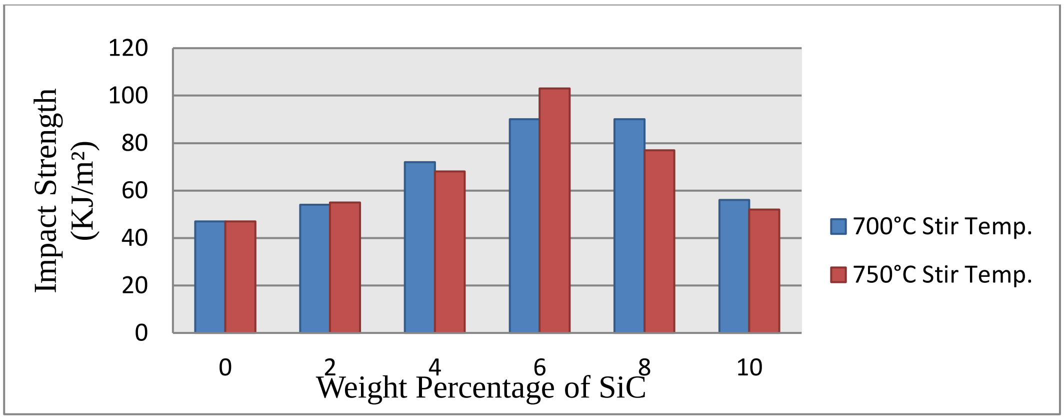

Figure 3.4 Variation in impact strength with wt *% of silicon carbide particles*

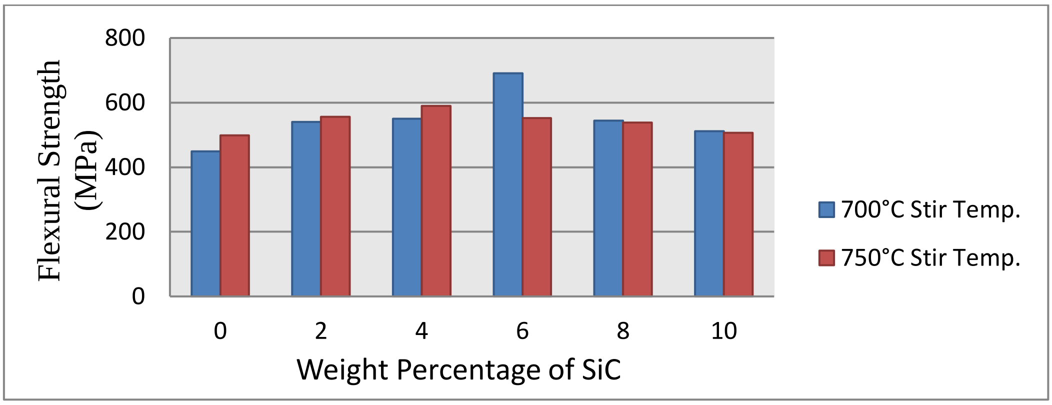

Figure 3.5 Variation in flexural strength with **wt** *% of silicon carbide particles.*

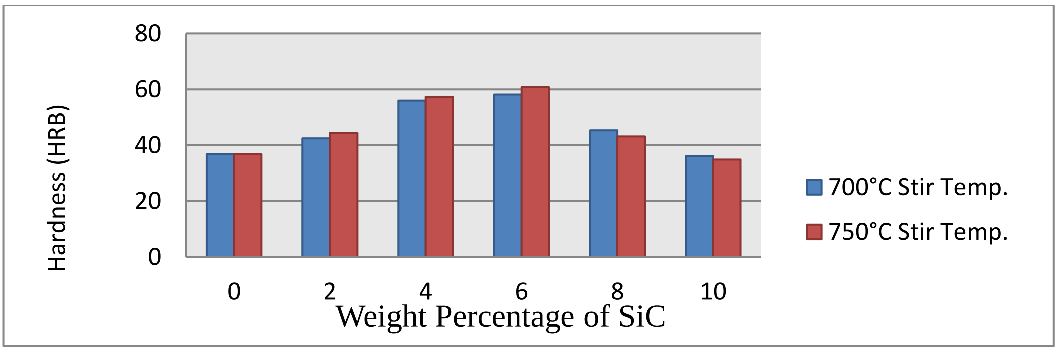

Figure 3.6 Variation in Hardness with **wt** *% of silicon carbide particles*

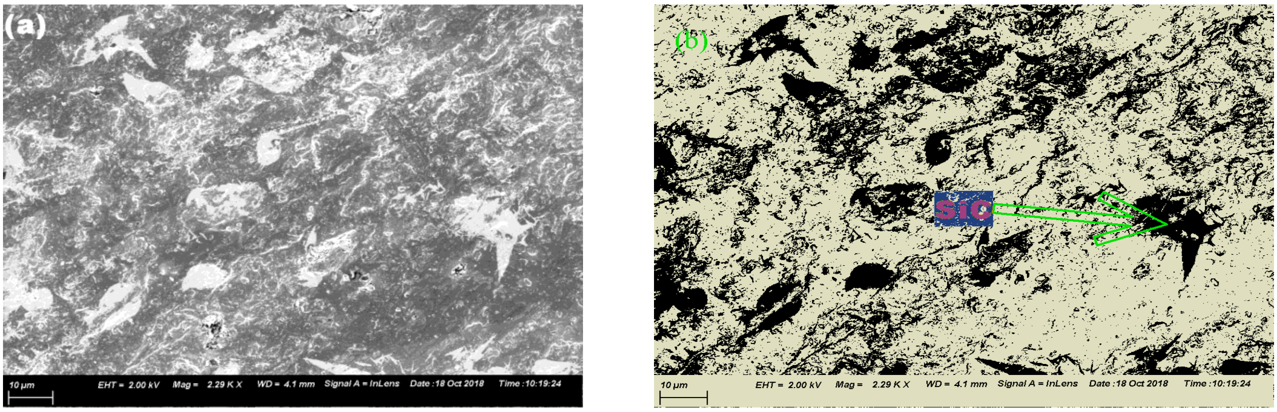

Plate 1: (a) Shows SEM micrograph of composites stirred at 700^{0}C containing 2 wt%. SiC and (b) shows how the particles distribution using image analyser.

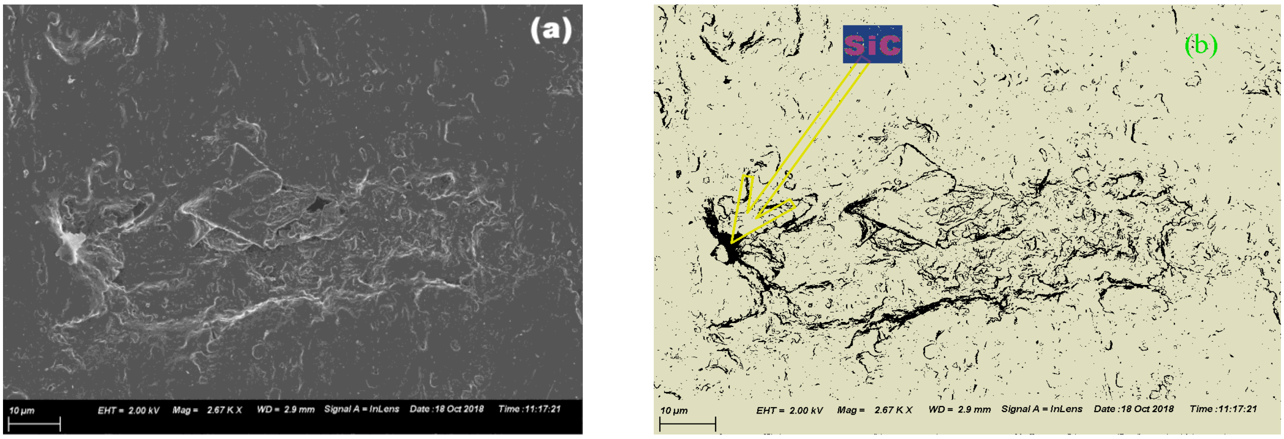

Plate 2: (a) Shows SEM micrograph of composites stirred at 750^{0}C containing 2 wt%. SiC and (b) shows the particles distribution using image analyser

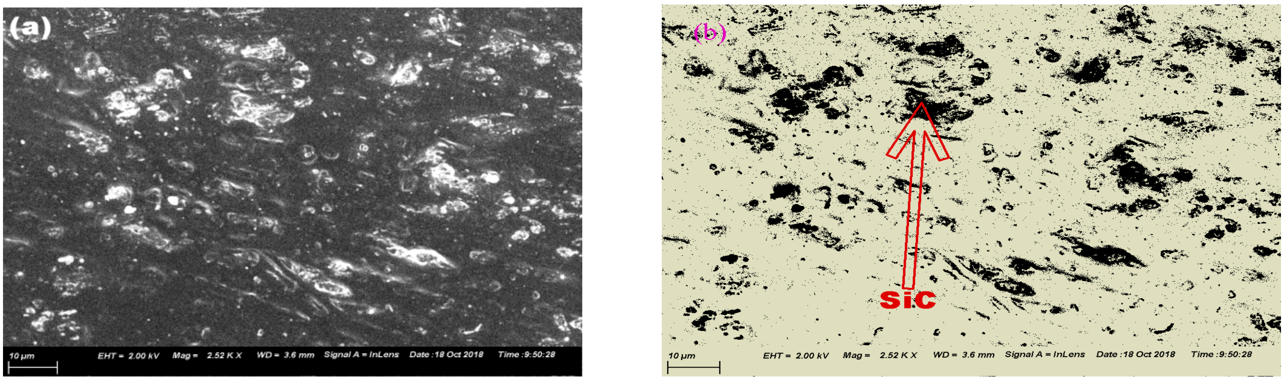

Plate 3: (a) Shows SEM micrograph of composites stirred at 700^{0}C containing 4 wt%. SiC and (b) shows the particles distribution using image analyser

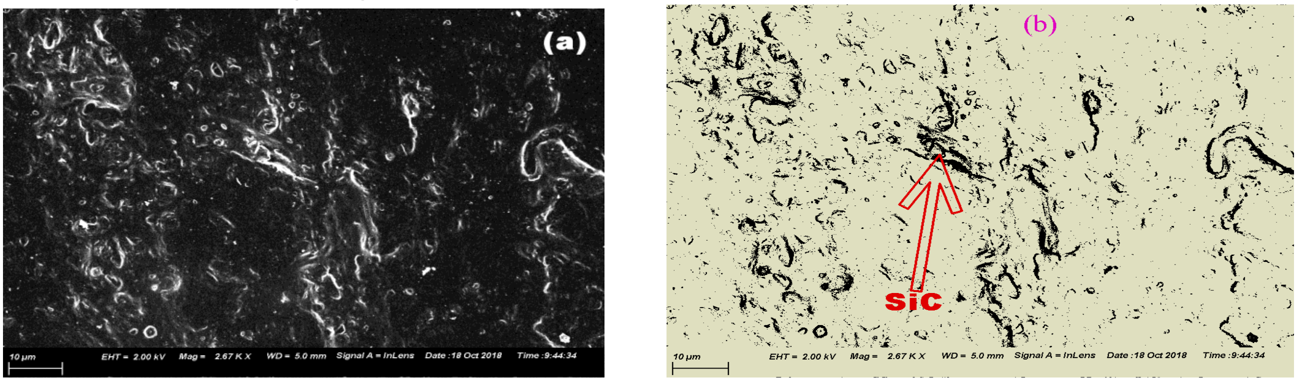

Plate 4: (a) Shows SEM micrograph of composites stirred at 750^{0}C containing 4 wt%. SiC and (b) shows the particles distribution using image analyser

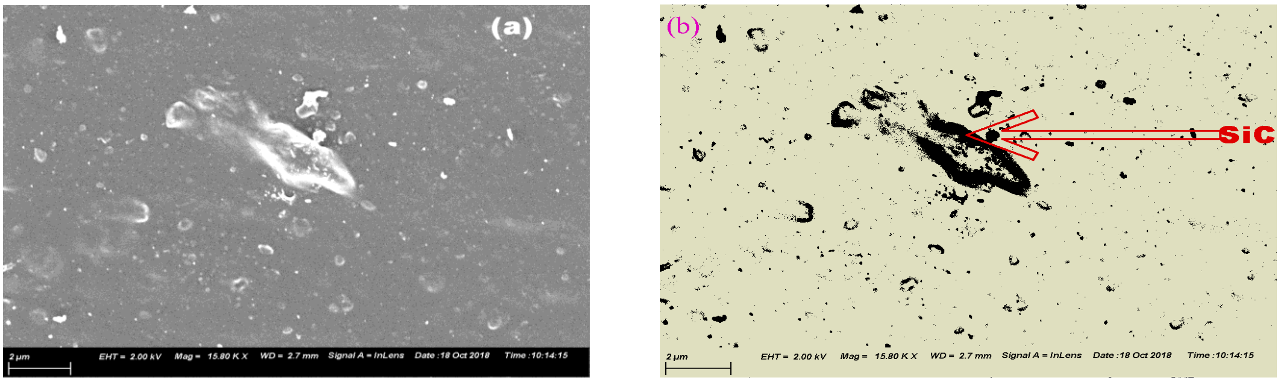

Plate 5: (a) Shows SEM micrograph of composites stirred at 700⁰C containing 6 wt%. *SiC and (b) shows the particles distribution using analyser*

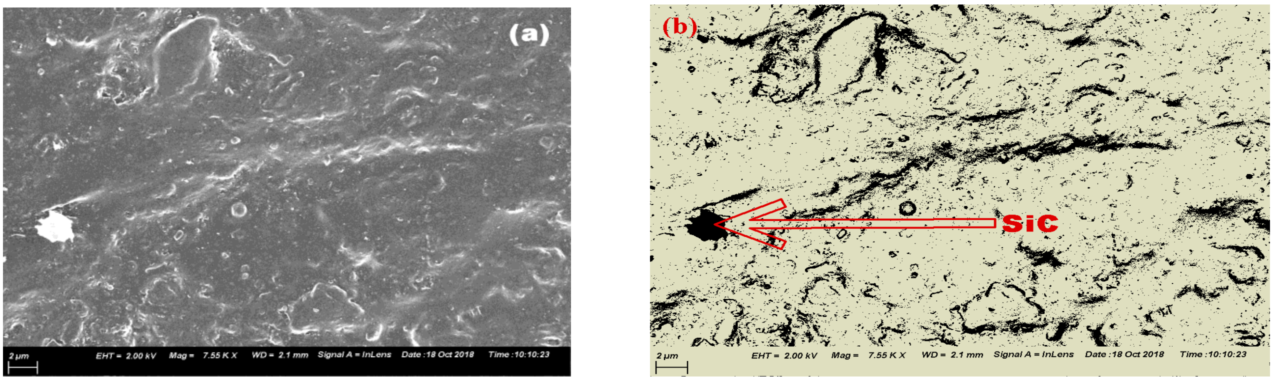

Plate 6: (a) Shows SEM micrograph of composites stirred at 750⁰C containing 6 wt%. *SiC and (b) shows the particles distribution using image analyser*

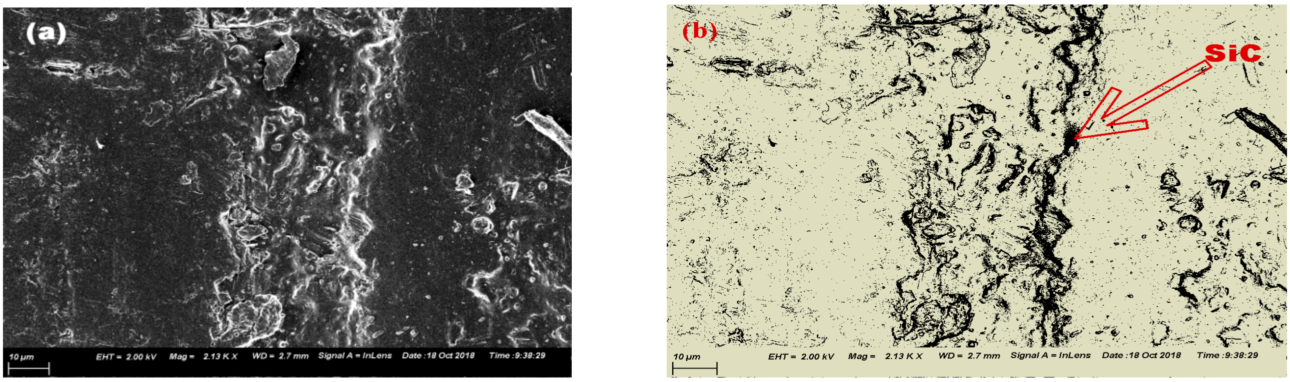

Plate 7: (a) Shows SEM micrograph of composites stirred at 700⁰C containing 8 wt%. *SiC and (b) shows the particles distribution using image analyser*

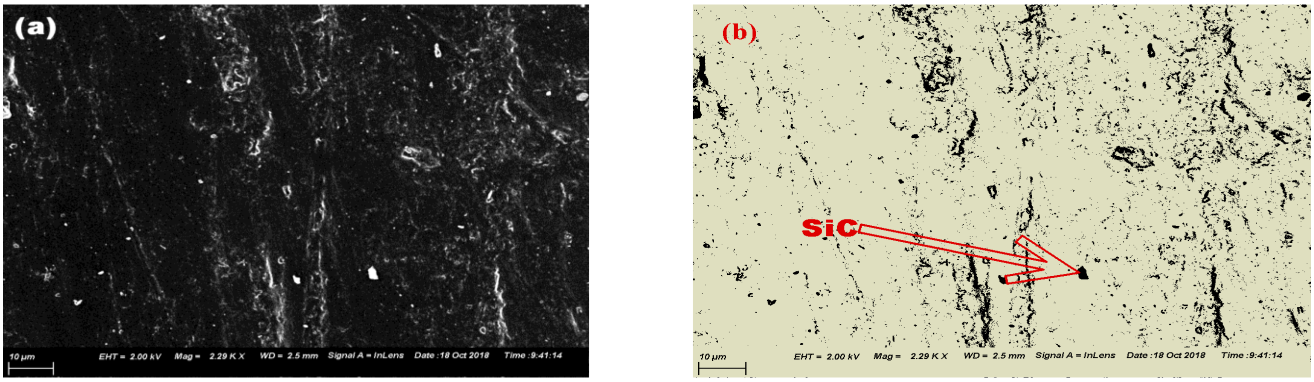

Plate 8: (a) Shows SEM micrograph of composites stirred at 750⁰C containing 8 wt%. *SiC and (b) shows particles distribution using image analyser*

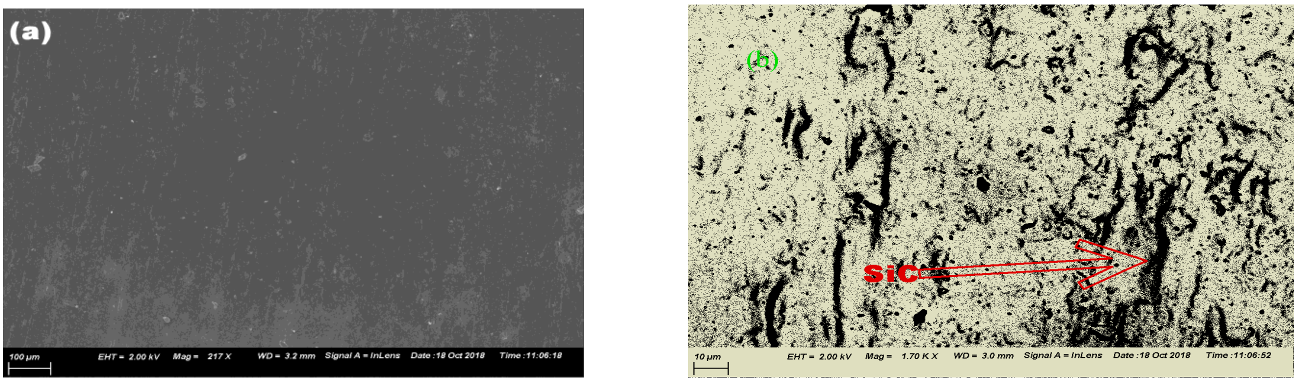

Plate 9: (a) Shows SEM micrograph of composites stirred at 700^{0}C containing 10 wt%. SiC and (b) shows particles distribution using image analyser

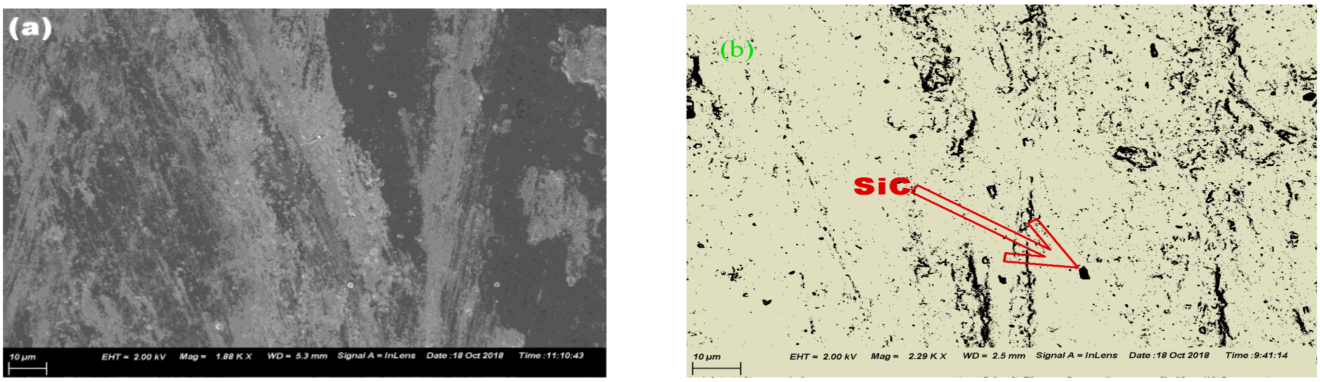

Plate 10: (a) Shows SEM micrograph of composites stirred at 750^{0}C containing 10 wt%. SiC and (b) shows the particles distribution using by image analyser

3.2 Discussion

Based on the results obtained, Figure 2.1 shows the influence of SiC addition on the density of composites. The graph shows that, as the SiC particles content in the composite increases in the matrix the density of the RAMC composites decreases. Slight decrease in the density was observed due to the brittle nature of SiC particles, which act as micro void initiator in the matrix and it can also be due to the presence of entrapped gases and shrinkage porosity in the prepared composite. The results obtained is in line with the works in [16], [17] and [18] who also observed that density of aluminum metal matrix composites reinforced by particles of silicon carbide slightly decreased with the increase of SiC in the matrix.

Figure 4.2 shows the variation of tensile strength with the addition of the reinforcement. The addition of 2 – 4 %Wt SiC gives highest strength of about 76% and 90% strength increment respectively when compared with base material. Even though, tensile strength decreases at higher percentage (8 – 10%) of SiC in the composites but still have improved strength compared with base (matrix) material, the degradation of tensile strength at higher content of reinforcement was similar to observation of [10] who reported that at certain percentage of additive the mechanical property will decrease. The samples of 750^{0}C composites have better tensile strength compared with samples of 700^{0}C.

From figure 3.3, the compressive strength of both types of specimens processed at 700^{o}C and 750^{o}C, decreases as the percentage of SiC addition increases in the matrix. The brittle nature of the reinforcing materials (SiC) plays a significant role in degrading the compressive strength of the composites, since the unreinforced alloy have the highest compressive strength value, indicating that addition of SiC material to recycled aluminum cans matrix alloy reduces the compressive strength.

Figure 3.4 shows the variation in toughness of the specimens for different SiC %wt in the produced composites. It implies that the increase in reinforcement above 6 – 8 wt% will reduce the toughness of the developed composite. Similar observation was reported by [19]. It was observed from figure 3.4; the highest value of toughness is achieved at 8% with increment of about 119% when compared to unreinforced base material. Also composites processed at 750ºC stir temperature have improved impact strength when compared with samples of composite prepared at 700ºC stirring temperature.

From Figure 3.5, it is observed that the addition of reinforcement (SiC) of different percentages improved flexural strength of produced recycled aluminum matrix composites materials at both stirring temperatures. The Figure shows that, the increment of reinforcement above 4 – 6 wt% depending on the stirring temperature reduces the flexural strength of the produced recycled aluminum matrix composites. Similar observation was reported by [20]. RAMC composite samples (700 and 750ºC) shows variation in strength as the percentage of reinforcement increases in matrix but specimens stirred at 700ºC has maximum increment of 53% at 6 wt% SiC when compared with that of 750ºC that has maximum increment of 31% at 4 wt% SiC.

It was observed that there is marked increase in hardness with increasing weight percentage of SiC in recycled aluminum metal matrix composites which is in line with the earlier work done by [21], who also found that the addition of SiC particle to aluminum matrix increases hardness of the composite. It was observed from figure 3.6 that the increment in hardness was obvious at 6 %Wt of SiC and then reduced drastically at the higher content of SiC in the composites of both stirring temperatures; the increase in hardness may be attributed to addition of SiC particle and the reduction may be due to clustering and segregation of SiC particle experience at the higher percentage of SiC content in the RAMC, similar observation was reported by [11]. Generally, composites structure of recycled aluminum cans reinforced with SiC particles revealed a good homogeneous distribution of SiC particle in the matrix alloy. The SiC particles were found to be well dispersed in Al matrix at lower content of (2 – 6 wt%.) but at higher content (8 and 10 wt%) of SiC particulate clustering, agglomeration and segregation of SiC particle powder were observed in the SEM micrograph of the samples which may be responsible for the declined in mechanical properties at the higher content of SiC in the RAMC composite. Some minor clustering and segregation of SiC particles were seen in plates 5-10 of the SEM micrograph, non-homogenous distribution of particles can be as a result of non-uniform mixing of the particles in the composite during the fabrication process, likewise segregation of particles may also occur during solidification, when the aluminum dendrites solidify first, which may be rejecting the SiC particle at liquid-solid interfaces which may cause the segregation of inter dendrites region. SEM micrograph shows three different areas in the sample, bright areas (matrix), diffused area and dark areas (SiC rich area) as showed in plates 2–10 which were analysed by image analyzer.

4. CONCLUSION

The recycled Aluminum cans metal matrix composites has been developed and Characterised and the following conclusions were made:

- The properties of the developed recycled aluminum cans matrix composite depend on many factors such as manufacturing technique, processing parameters and percentage of reinforcement.
- There is a slight difference between the densities of unreinforced matrix material and prepared composites material, the density decrease as the weight percentage of SiC increases in the composites. Therefore, the produced composites (RACM) are lighter with enhanced mechanical properties. Marginal improvement in hardness, impact strength, Tensile Strength, Flexural strength is observed in the composites with additions of weight percentage of SiC reinforcement, when compared with unreinforced base material.
- Generally, the composites stirred at 750ºC have better variation and enhance properties when compared with that of 700ºC while both RAMC mechanical properties were improved when compared with base material

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