Tin (II) Chloride a Suitable Wetting Agent for AA1200 - SiC Composites

S. O. Adeosun, E. I. Akpan, S. A. Balogun, A. S. Abdulmunim

***Abstract*—**SiC reinforced Aluminum samples were produced by stir casting of liquid AA1200 aluminum alloy at 600-650ºC casting temperature. 83µm SiC particles were rinsed in 10g/l, 20g/l and 30g/l molar concentration of $Sncl_2$ through cleaning times of 0, 60, 120, and 180 minutes. Some cast samples were tested for mechanical properties and some were subjected to heat treatment before testing. The $SnCl_2$ rinsed SiC reinforced aluminum exhibited higher yield strength, hardness, stiffness and elongation which increases with cleaning concentration and time up to 120 minutes, compared to composite with untreated SiC. However, the impact energy resistance decreases with cleaning concentration and time. The improved properties were attributed to good wettability and mechanical adhesion at the fiber-matrix interface. Quenching and annealing the composite samples further improve the tensile/yield strengths, elongation, stiffness, hardness similar to those of the as-cast samples.

***Keywords*—**Al-SIC, Aluminum, Composites, Intermetallic, Reinforcement, Tensile Strength, Wetting.

I. Introduction

RESEARCH efforts have been focused on the hybrid composites, because of the combined effects of metallic and ceramic materials relative to the corresponding monolithic alloy. Remarkable properties of these composites such as high strength and modulus accompanied with the excellent high temperature resistance represent these materials as appropriate candidates for automotive and aerospace applications [1]-[3]. Aluminum alloys reinforced with SiC are among the most reputed composites, with a considerable efficiency in all fields of technology due to their high modulus, high specific stiffness, low thermal expansion coefficient, good workability and wear resistance [4]-[6]. Reinforcement by particles or short fibers of SiC has proved to be especially advantageous since it offers composite materials having virtually isotropic properties at low cost. Strength as much as 400, 380 and 360 MPa has been obtained for AA6061-SiC, AA6063-SiC and AA7072-SiC composites respectively with excellent corrosion resistance [7].

Despite its excellent properties, cast Al-SiC composites suffer detrimental effects such as segregation of particles, higher porosity level, extensive interfacial reaction due to higher processing temperature and poor wettability between molten Al and the SiC [8]-[10]. This may be due to interfacial de-bonding of the SiC particles from the soft Al matrix during loading [11]. It has also been noted that poor adhesion may lead to local yielding due to alteration of the local stress state at the de-bonded interface [12]. In order to achieve high level of mechanical properties in the composite, a good interfacial bonding (wetting) between the dispersed phase and the liquid matrix has to be obtained [13]. Non-wettability of the particles can be improved by coating the particles with metals such as Ni, Cu, Ag addition of surface active elements such as Mg into liquid Al or preheating of the particles before addition into liquid Al [7], [10], [14], and [15]. Preheating the SiC particles to cause surface oxidation of the particles before introducing them into the matrix has also been studied [16]. In another approach, authors incorporate SiO_2 powders into the SiC preforms which also proved to be beneficial [17] to prevent formation of the unwanted phase Al_4C_3. The use of 6 volume % SiO_2 either in the form of quartz or cristobalite powders of ≈ 5µm average particle size, completely hindered formation of Al4C3. Later on, the same group tested a simple method by coating the SiC particles with 0.1 volume fraction of colloidal silica (0.02–0.06µm particle size) [18] and observed that formation of Al_4C_3 was also prevented. A recent trial has been to a change the atmosphere of casting from argon to nitrogen during pressureless infiltration which also significantly improves the wetting of SiC by the liquid aluminum alloy and consequently, substantially enhances infiltration [1].

According to studies [19]-[24] the alloying additions do not show a significant influence on wettability: Pb and Sn improve wetting slightly by decreasing the surface tension of aluminium [20], [21], [24]; Cu deteriorates wetting [20]; Si has a marked effect of wettability improvement only at temperature higher than 1000°C [20], [23], while at low temperature its positive role causes the inhibition of Al_4C_3 formation. Sobczak et al [25] confirms that the use of titanium improves wettability and eliminates the formation of Al_4C_3. The use of oxidized SiC is associated with difficulty in the control of uniformity and thickness of SiO2 layer formed. In addition the use of high temperatures and long holding times increase processing costs. Moreover, non-environmental friendly gases (CO_2 and CO) are emitted during formation of the SiO_2 layer.

One prominent finding on wettability of SiC in Aluminium matrix is that wettability is achieved by lowering the surface tension of the liquid aluminium [1]. Another important finding is the fact that wetting in the Al/SiC system belongs to the reactive wetting category [25]. $SnCl_2$ is widely used as a reducing agent (in acid solution), and in electrolytic baths for

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tin-plating. Tin (II) chloride also finds wide use as a reducing agent for silvering mirrors, where silver metal is deposited on the glass with the aid of the $SnCl_2$. It acts on the surface of the silver to reduce the ion and thereby enhancing deposition by reactive wetting [26]. It is a non-toxic, cheap and readily available chemical substance. It is believed that the action of $SnCl_2$ on the surface of SiC will enhance its wettability with Aluminium alloys in the liquid phase.

In this study the effect of $SnCl_2$ as a wetting agent on the mechanical properties of Al-SiC composite produced by stir casting has been investigated. Casting schedules were designed by authors according to experience. Conventional stir casting was used and mechanical test were conducted to study the effect of the action of the cleaning agent with regard to concentration and time of cleaning.

TABLE I
COMPOSITION OF AA 1200 AL ALLOY

Element	Si	Fe	Cu	Mg	Mn	Zn	Ti	Br	Sn	Pb	Al
% Composition	0.2041	0.46979	0.05936	0.03565	0.10493	0.00597	0.01750	0.001	-0.01	0.005	98.95

II. EXPERIMENTAL PROCEDURE

Solid particles (83µm) of Silicon carbide (containing 53% Si, 3% K, 11% Ca, 2.2% Mn, 5.6% Fe, Cu 7%, 18% C) collected from manufacturers were cleansed in different concentration (10/l, 20g/l, and 30g/l) of tin chloride and at a varying cleaning time (60, 120, and 180min).

AA1200 aluminium received from Nigalex, Oshodi, Lagos was charged into a crucible in a muffle furnace and heated to a temperature of about 800°C for about 1 hour to obtain molten aluminium. The molten aluminium was transferred to a stainless steel cup where silicon carbide particles where added and stirred properly with the aid of a glass rod. The mixture was cast into the mould and allowed to solidify.

Cast samples were machined to standard sizes for mechanical test before heat treatment. Heat treatment was carried out in a box type furnace by heating the samples to 400°C and cooled in two conditions; furnace cooled and water cooled. Hardness of cast samples were measured using the Rockwell hardness tester (model no E66236/142C) at a dwell time of 10 seconds. Tensile test was done on a M500 Universal testing machine. Impact test of the samples was carried out using the Charpy impact testing machine - model no: E742474.

III. RESULT AND DISCUSSION

A. Hardness

Fig. 1 shows the variation of the composite hardness number with cleaning time and concentration of $SnCl_2$ in the as-cast condition. The hardness increases to a maximum at 120 minutes cleaning time for all concentrations but falls afterwards at cleaning time of 180 minutes. When the SiC was just dipped in the cleaning and removed immediately (i.e. 0 cleaning time) the hardness seem not to follow a trend in terms of concentration of the cleaning agent but as the time of cleaning increased the effect of concentration seem to show increasing hardness as the concentration increases.

Figs. 2-4 show the effect of heat treatment on the hardness property of the composite at different concentration and time of cleaning. These figures show that heat treatment strongly influenced the hardness of the composite. Hardness was highest for quenched samples in all cases followed by annealed samples. The highest value of hardness (95.25 HRB) was obtained for quenched samples at a 30g/l concentration of $SnCl_2$ for 120 minutes cleaning time. Conventional AA 1200 alloy shows a hardness value of 62HRB while that reinforced with SiC without cleaning shows a hardness of 82HRB for as cast samples. This shows that cleaning the SiC particles before use gives about 16.16 % increase over that of un-cleansed particles and about 54 % over AA1200 without reinforcement.

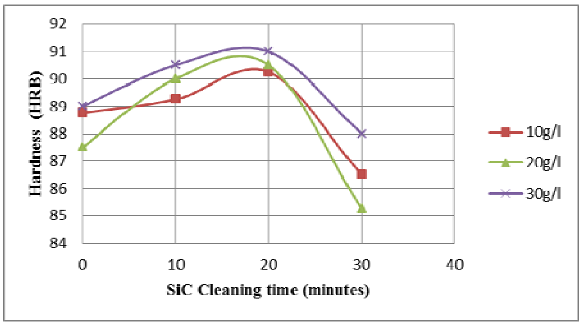

Fig. 1 Variation of Brinnel Hardness number with cleaning time and concentration

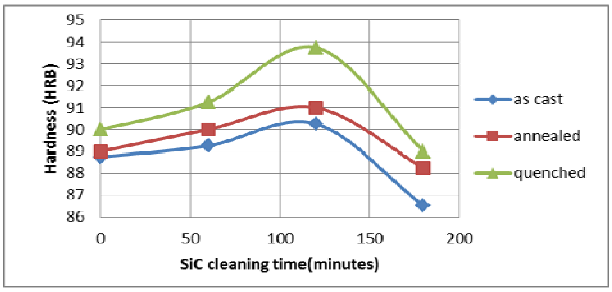

Fig. 2 Effect of heat treatment on hardness of processed composites (10g/l concentration of SnCl2)

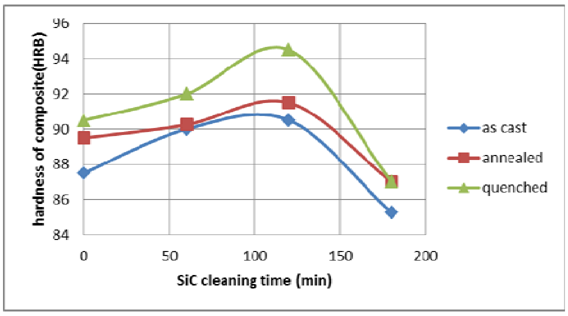

Fig. 3 Effect of heat treatment on hardness of processed composites (20g/l concentration of $SnCl_2$)

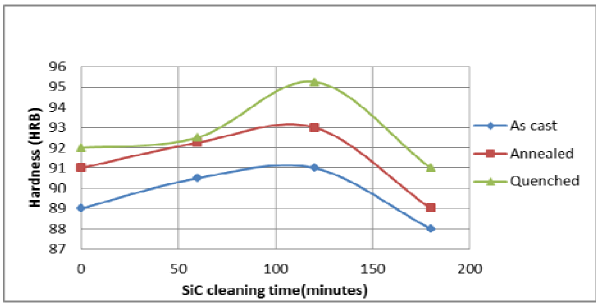

Fig. 4 Effect of heat treatment on hardness of processed composites (30g/l concentration of $SnCl_2$)

B. Tensile Strength

Ultimate tensile strength of AA1200 cast samples with cleaned SiC particles as reinforcement is shown in Figs. 5-8. Fig. 5 shows the variation of tensile strength with concentration of $SnCl_2$ and time of cleaning in the as-cast condition. Tensile strength increased seem not to be affected by the cleaning time at lower cleaning times but at cleaning times above 120 minutes it decreases steadily. However, tensile strength increases with increase in concentration of the cleaning agent for all conditions.

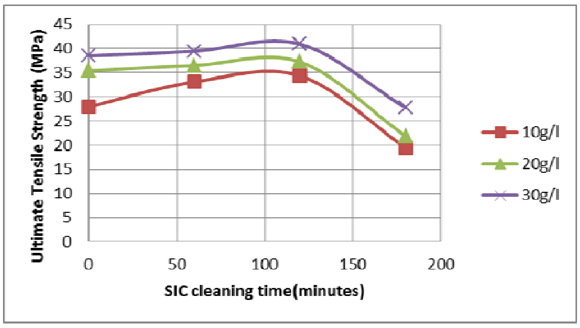

Fig. 5 Variation of Ultimate Tensile Strength with concentration and time of cleaning

Figs. 6-8 show the combined effect of heat treatment, cleaning time and concentration of the cleaning agent on the ultimate tensile strength of the composite. Heat treatment seem not to show any influence on the cast samples except for those cast with particles cleaned with 30g/l concentration of wetting agent. The highest tensile strength (47.024 MPa) was obtained with samples cast with particles cleaned with reagent concentration of 30g/l and a cleaning time of 120 minutes for all heat treatment conditions.

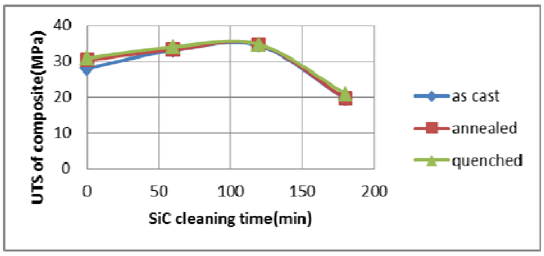

Fig. 6 Effect of heat treatment on UTS of processed composites (10g/l concentration of $SnCl_2$)

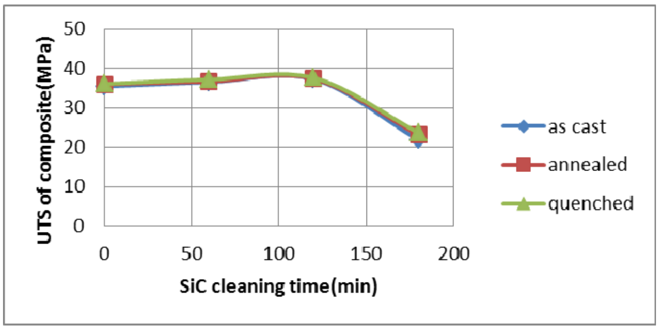

Fig. 7 Effect of heat treatment on UTS of processed composites (20g/l concentration of SnCl2)

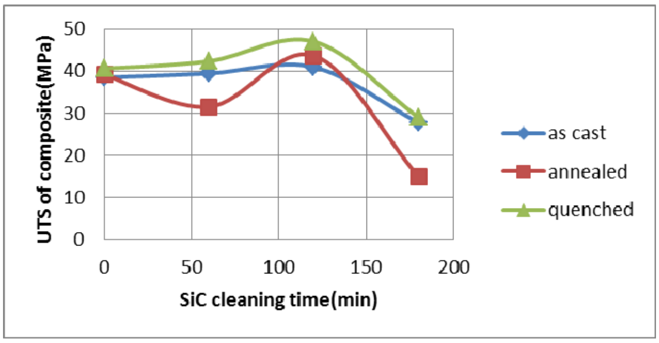

Fig. 8 Effect of heat treatment on UTS of processed composites (30g/l concentration of SnCl2)

C. Elongation Responses

Elongation responses of cast AA1200 composites with tin chloride cleaned SiC particles are shown in Figs. 9–12. Elongation response in the as-cast condition seems not to follow a trend with respect to cleaning time and concentration of the cleaning agent (see Fig. 9). Highest elongation (12.818%) attainable was obtained in samples cast with particles that were dipped and removed immediately in 30g/l concentration of $SnCl_2$ in the as-cast condition.

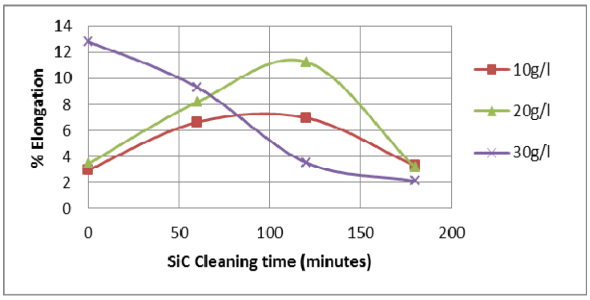

Fig. 9 Variation of % Elongation with cleaning time and concentration

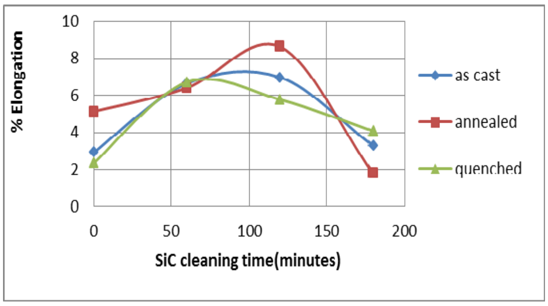

Fig. 10 Effect of heat treatment on % Elongation of processed composites (10g/l concentration of $SnCl_2$)

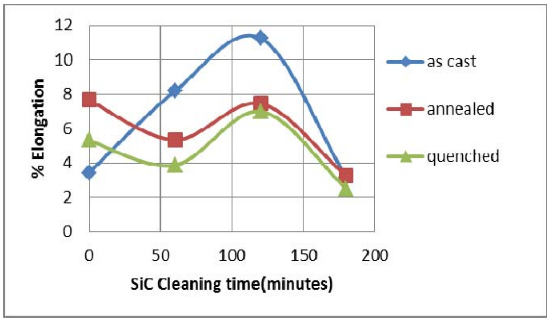

Fig. 11 Effect of heat treatment on % Elongation of processed composites (20g/l concentration of SnCl2)

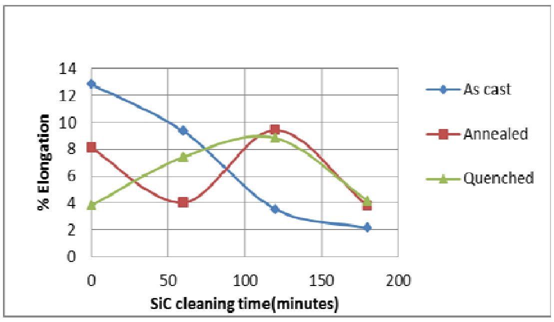

Fig. 12 Effect of heat treatment on % Elongation of processed composites (30g/l concentration of $SnCl_2$)

D. Impact Energy Resistance

The impact responses of the composite as given in Figs. 13-15 decreases as the cleaning time increases up to 180 minutes. Though, the lowest value (5.42J) of the impact responses for the cleaned SiC was same as the un-cleaned SiC aluminium composite; it was also observed that unlike the strength and hardness responses, the impact strength decreases from as cast (uncoated SIC composite; 10.85J), to annealed (8.13J) and finally to quenched composite (5.42J), except for slight differences in composites with cleaning concentration of 20g/l (see Fig.15).

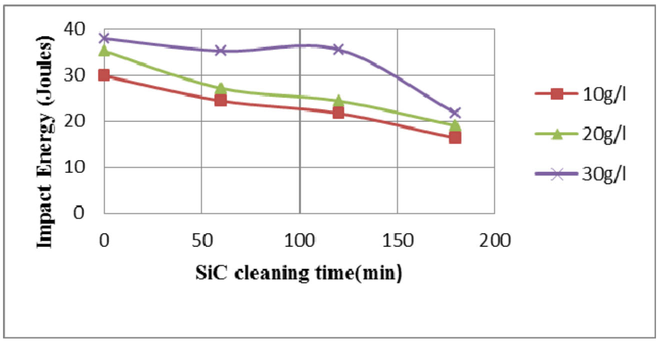

Fig. 13 Effect of heat treatment on Impact strength of processed composites (10g/l concentration of $SnCl_2$)

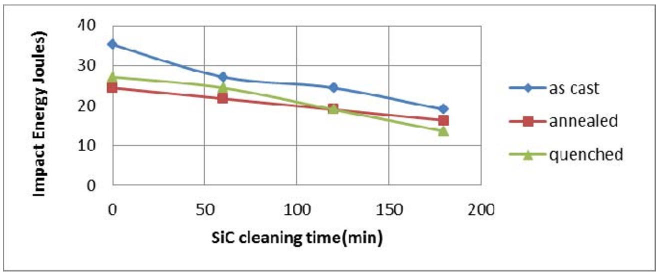

Fig. 14 Effect of heat treatment on Impact strength of processed composites (20g/l concentration of $SnCl_2$)

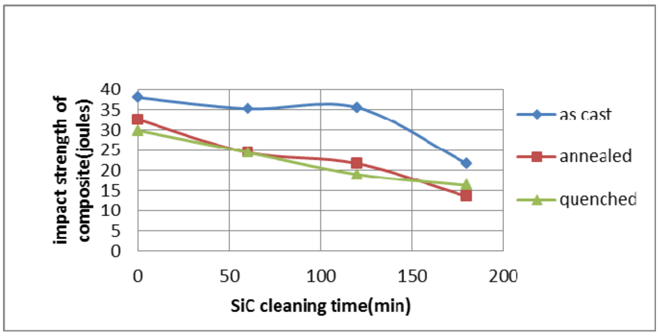

Fig. 15 Effect of heat treatment on Impact Strength of processed composites (30g/l concentration of $SnCl_2$)

IV. Conclusion

This study has been able to ascertain the following;

1. That $SnCl_2$ is a suitable cleaning agent for surface wetting of SiC particles for incorporation into Al matrix during stir casting.
2. The concentration of $SnCl_2$ is a significant variable in the surface cleaning of SiC that must be taken into consideration.
3. It is also noted that cleaning time plays an influencing role in the quality of the outcome.

4. Impact energy, hardness and tensile elongation were significantly affected by the wetting behaviour whereas minimal effect was noticed on tensile strength.
5. Tensile strength as much as 47.024 MPa was obtained for the AA1200-cleaned SiC filled composite.
6. Impact strength was adversely affected whereas tensile elongation and hardness were favoured in relation to time and concentration of cleaning.

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