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# MECHANICAL BEHAVIOUR OF MODIFIED Al-Si-Cu-Mg ALLOY AND REINFORCED WITH SiC UNDER AMBIENT TO ELEVATED TEMPERATURE

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**ABSTRACT**

The Al–Si-Cu-Mg alloy as potential high temperature materials for automobile industry, the mechanical properties of alloy was inspected at distinctive temperatures from ambient to 350 °C. Al–Si-Cu-Mg alloy and composite was made by stir casting technique. Microstructural studies showed that sensibly uniform distribution of silicon particles. It was found that the tensile behaviour of alloy was decreasing with increasing of temperature. The effect of temperature on tensile behaviour of the alloy had been surveyed and it revealed that behaviour of Al–Si-Cu-Mg alloy and composites as changed from ductile to brittle mode with extension of temperature condition.

**Keyword:** aluminium alloy, mechanical behaviour, high temperature condition, metal matrix composite, stir casting.

## 1. INTRODUCTION

There have been solid moves, to make a light weight as a factor for fuel consumption of vehicles with lower radiations on the automotive industry. Cast eutectic Al-Si matrix and composites are widely used in automobile parts manufacturing due to low density, high strength, wear and corrosion resistance [1-7].

Copper is a key alloying parts in Al-Si alloys and allows extraordinary heat treatability to castings inferable from the broad solid dissolvability in aluminium matrix. Moreover, addition of Cu and Ni aluminium alloy is improving the mechanical properties. The expansion of silicon, beside decreasing the coefficient of thermal expansion takes an aluminium alloy with extraordinary wear, disintegration, machining qualities. The particle reinforcement of metal matrix composites is commonly used for mechanical and tribological applications [7-15].

The Al-Si alloy are potential high temperature fundamental material in automobile application due to brilliant and incredible cast limit, low thermal coefficient. Material examinations of piston and chamber liner shows liberal drop in hardness at the exhaust side exhibiting high working temperatures. The high silicon content, however extended the life, yet couldn't kept up high working temperatures in conclusion seized. The chamber head working at 250 °C with aluminium silicon alloy will orderly lose its accomplished hardness in T6 condition, the issue of superheat may add to the breaks in piston head base deck or in the exhaust valve bridge [16-20].

Automotive cast of A319 compounds are progressively utilized as a part of the assembling of engine blocks because of a blend of good ease properties and mechanical quality. In minor expansion are regularly made to high quality created and hindering recrystallization amid heat treatment, which disengagements [21-28]. In present research to investigate the mechanical properties of Al-Si-Cu-Mg alloy with Fe, Ni and Ti elements and reinforced with silicon carbide (SiC) from room temperature and elevated temperature (200°C, 350 °C).

## 2. EXPERIMENTAL PROCEDURE

### 2.1 Materials preparation

The chemical composition in wt% of the as received Al-Si-Cu-Mg alloy (ANSi319) is listed in Table1. The addition of iron, nickel and titanium will be carried out using Al-Si-Cu-Mg master alloys respectively. Table2 shows the actual compositions of the alloys used in the present study and reinforced with 3wt% SiC. The material used to obtain the present alloy was melted at 850°C using stir casting process. The poring temperature maintained 850°C.

**Table-1.** Chemical composition of the as -received Al-Si-Cu-Mg alloy (ANSi319).

| **Element** (Wt %) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Si** | **Cu** | **Fe** | **Mg** | **Mn** | **Zn** | **Ni** | **Ti** | **Al** |
| 6.40 | 3.5 | 3.1 | 0.06 | 0.2 | 0.3 | 0.1 | 0.08 | Balance |

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**Table-2.** Chemical composition of modified Al-Si-Cu-Mg alloy.

| **Element** (wt %) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Si | Cu | Fe | Mg | Mn | Zn | Ni | Ti | Al |
| 7 | 5 | 5 | 0.5 | 0.2 | 0.3 | 2 | 1 | Balance |

**2.2 Microstructural analysis**

The samples for metallographic studies were sectioned from the cast sample at different location to understand the structural changes as well as distribution of Al-Si-Cu-Mg alloy matrix and SiC. The samples were polished and etched with keller's Agent to reveal the structure.

**2.3 Mechanical properties**

Tensile test at different temperature was conducted as per ASTM E8M and B557 standards. The sample was prepared proportional standard size as shown in figure1.Static tensile test of Al-Si-Cu-Mg alloy was carried out by tensile testing machine (model: UT 40 FIE) in the temperature range of room temperature to 350°C at constant strain rate (10-3 $s^{-}$1). Ultimate tensile strength, yield strength and percentage of elongation were determined. The yield stress or the stress at which the material begins to deform plastically, was determined by finding the point where a line parallel to the linear region. The hardness tests were conducted in accordance with ASTM standards using micro vicker's hardness testing machine. The hardness test was conducted using a steel ball indenter of 10mm diameter and load of 5kgf.

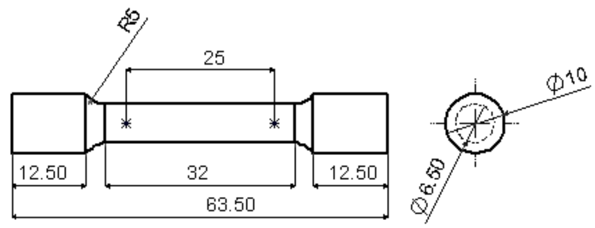


**Figure-1.** Tensile test dimensions as per ASTM E8M proportional size.

**3. RESULTS AND DISCUSSIONS**

**3.1 Microstructural observations**

Typical microstructures of the aluminium alloy and 3% wt. of SiC composites cast using cast iron die are shown in Figures 2(a, b, c, d). It is observed from the Figures 2 (c, d) that in the microstructure of the 3% wt. of SiC reinforced composite, the distribution of the SiC particles in the matrix is uniform and it is notable that there is no segregation of the particulates. An absence of segregation can be attributed to efficient and uniform mixing of the reinforcement in the stir casting.

VOL. 11, NO. 7, APRIL 2016 ISSN 1819-6608
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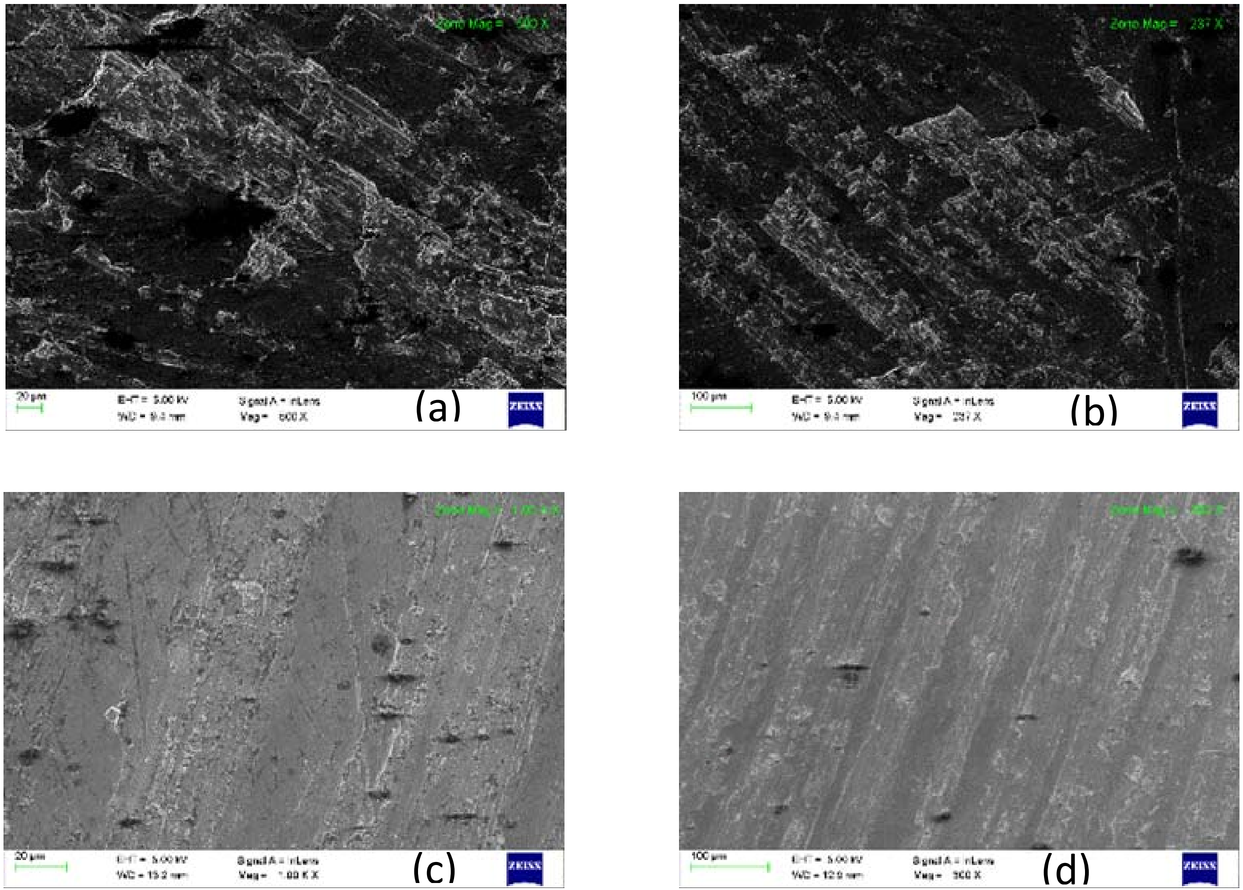


**Figure-2.** SEM Characterization of Al-Si-Cu-Mg Alloy and Al-Si-Cu-Mg Alloy with 3 wt% SiC for 20 and 100 µm in (a,b,c,d).

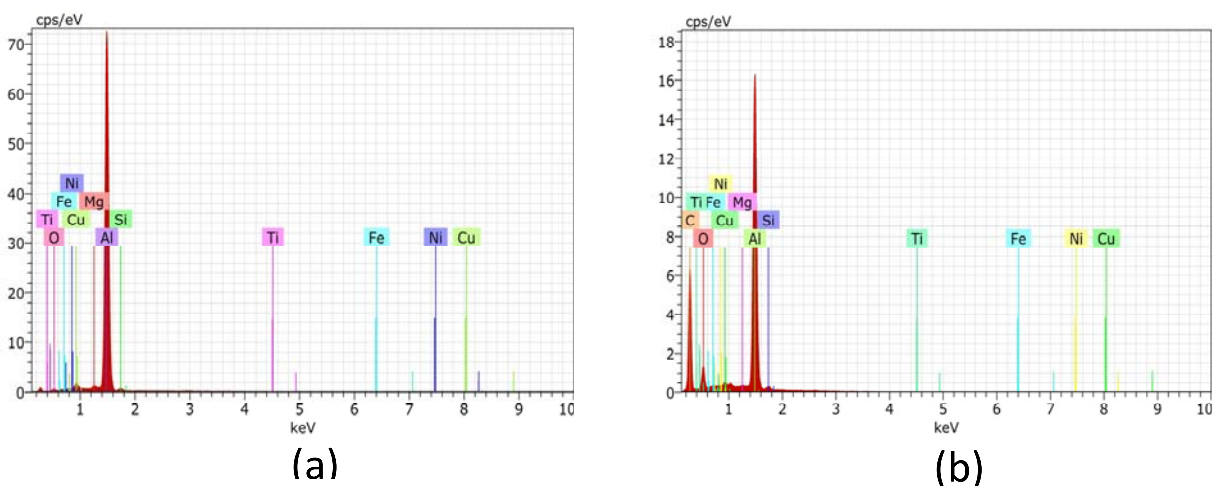


**Figure-3.** EDAX -Characterization of Al-Si-Cu-Mg Alloy and Al-Si-Cu-Mg Alloy with 3 wt% SiC for (a, b).

Energy dispersive spectroscopy (EDS) analysis of Al matrix near the Nano particles is shown in Figures 3 (a, b). The aluminium, silicon, copper, magnesium, iron, nickel and carbon peak in the EDS confirms the incorporation of SiC nanoparticles in Al-Si-Cu-Mg alloy. Also, the oxygen content is very low which indicates that the nanocomposites were well protected during casting.

ARPN Journal of Engineering and Applied Sciences



### 3.2 Mechanical properties

The tensile properties of modified Al-Si-Cu-Mg alloy and Al-Si-Cu-Mg alloy with 3wt % SiC at room and elevated temperature as summarized in Table-3. It is seen that the present alloys exhibit excellent mechanical properties at room and elevated temperatures. The ultimate tensile strength, yield strength and elongation at room temperature reach 159.56 MPa, 146.35 MPa, and 3.47 %, respectively as shown in Figure 4 and 5. For Al-Si-Cu-Mg alloy with 3wt % SiC, the ultimate tensile strength and yield strength are obviously increased, whereas the elongation is reduced, due to the addition of SiC as shown in Figure-6.

Now let us focus on the mechanical properties of Al-Si-Cu-Mg alloy and Al-Si-Cu-Mg alloy with 3wt % SiC at elevated temperature. As shown in Figures 4, 5, and 6 all alloy and composite shows a decrease in UTS and YS, and increase in EL with increase of temperature. It also seen that from figure, the UTS and YS of alloy is lower than the composite, but the EL of composite is lower than the alloy. This means that the increase in SiC content obviously results in strengthening effect.

**Table-3.** Mechanical properties of as cast of Al-Si-Cu-Mg alloy.

| S. No. | Materials | Temperature in (°C) | Yield strength in (MPa) | Ultimate tensile strength in (MPa) | Elongation in mm |
|---|---|---|---|---|---|
| 1 | Al-7%Si-3%Cu-0.5% Mg alloy | Room temperature | 146.35 | 159.56 | 3.47 |
| 2 | | 200°C | 80.44 | 128.24 | 4.07 |
| 3 | | 350°C | 74.72 | 121.38 | 4.39 |
| 4 | Al-7%Si-3%Cu-0.5% Mg alloy + 3%SiC | Room temperature | 172.44 | 188.16 | 1.37 |
| 5 | | 200°C | 143.61 | 163.21 | 1.83 |
| 6 | | 350°C | 112.17 | 128.14 | 2.45 |

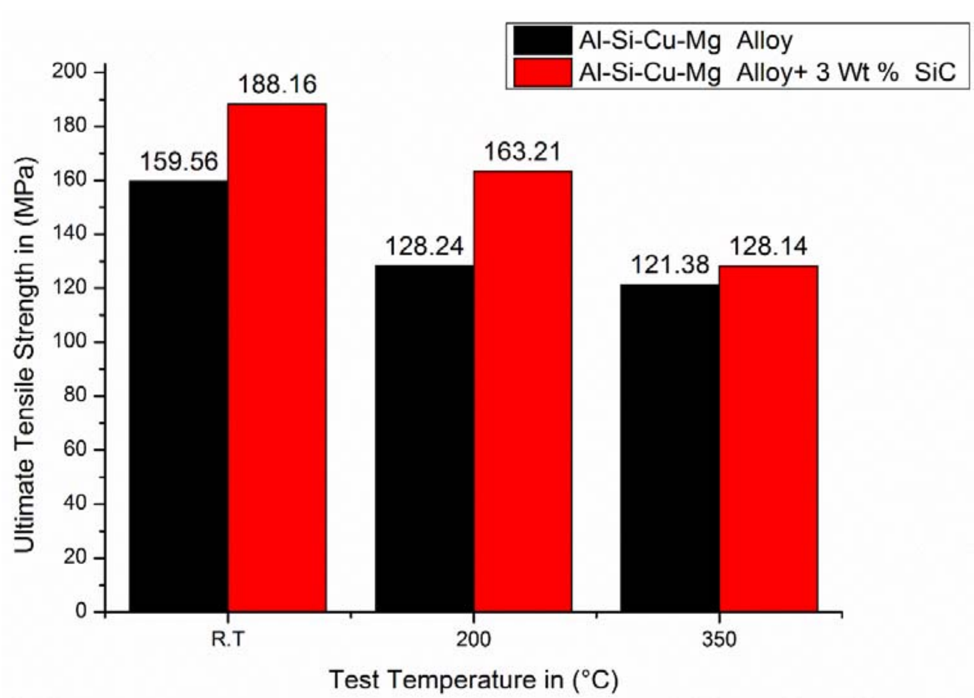


**Figure-4.** Ultimate tensile strength value for experiments at ambient and at high temperature.

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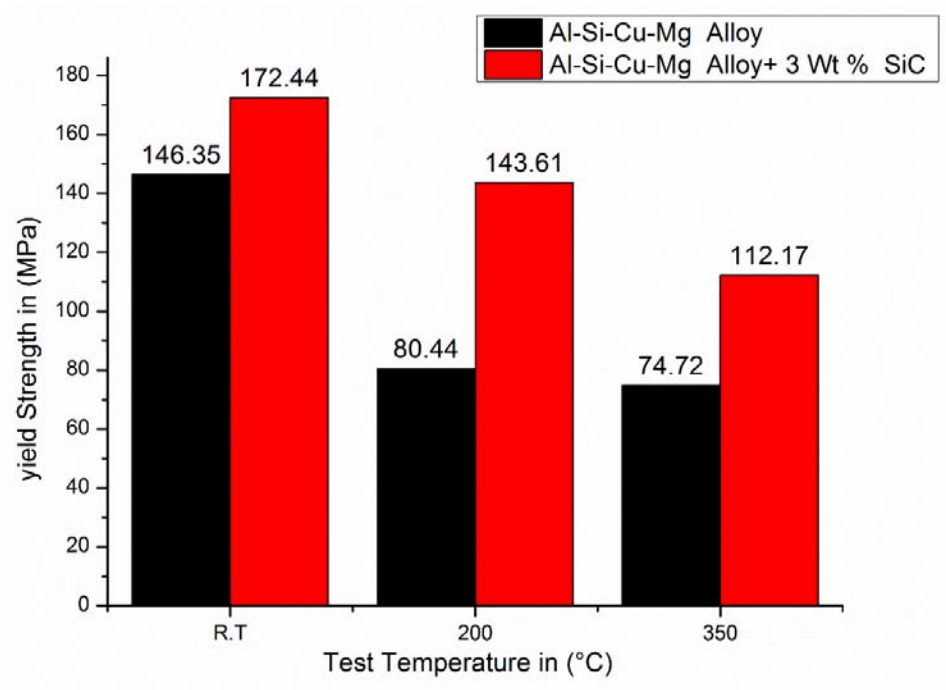


**Figure-5.** Yield strength value for experiments at ambient and at high temperature.

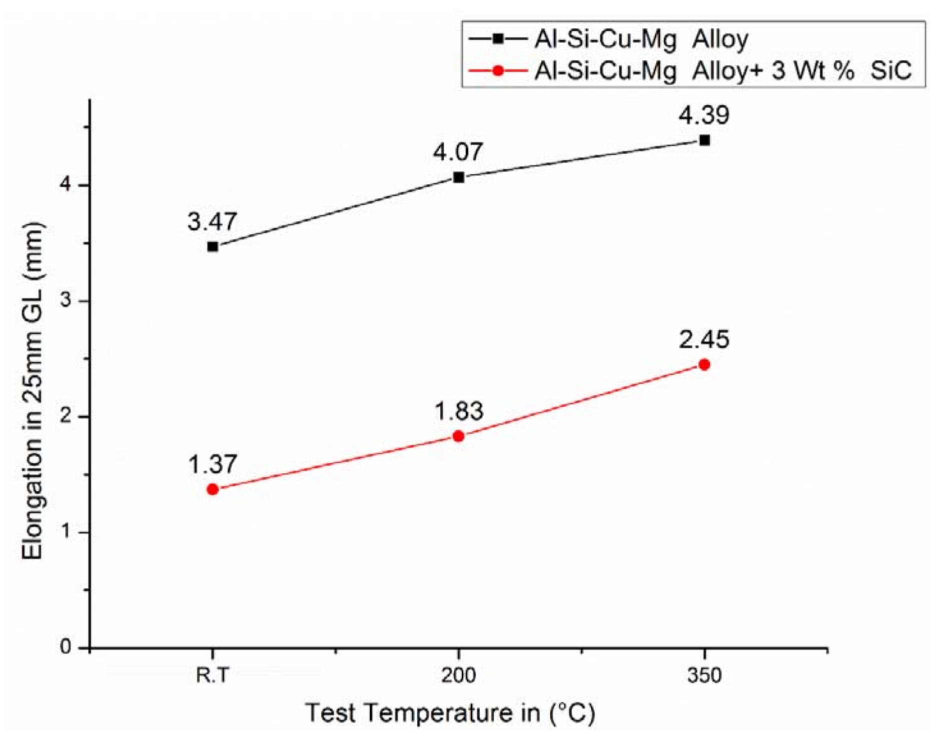


**Figure-6.** Elongation value for experiments at ambient and at high temperature.

The hardness of the modified Al-Si-Cu-Mg alloy and reinforced with 3wt % SiC as cast conditions is measured using a micro Vickers's hardness test at 5kgf. Before hardness measurements, each sample is polished and its opposite sides are made perfectly parallel. The mean hardness for 110 HV and 115 HV for modified Al-Si-Cu-Mg alloy and reinforced with 3wt % SiC.

ARPN Journal of Engineering and Applied Sciences




## CONCLUSIONS

- The modified Al-Si-Cu-Mg alloy alone improves the mechanical properties to a greater extent than that unmodified alloy at elevated temperature condition.
- Through the addition of Ni, Ti and Fe in Al-Si-Cu-Mg alloy with enhanced room temperature and elevated mechanical properties were developed. The UTS of the modified Al-Si-Cu-Mg alloy is 30% greater than the existing Al-Si alloy under elevated condition. In order to, further improved under elevated condition with addition of SiC was 20% greater than the modified alloy.
- The hardness and strength of composite are higher than that of alloy and they increase with the addition of SiC content.

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