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# Evaluation of Mechanical Properties and Characterization Study of Silicon Carbide Particulates Reinforced with Al2014 Alloy Composites Using Stir Casting Method

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**ABSTRACT:** The microstructure, mechanical characteristics, and tensile fractography of Al2014 alloy reinforced composites with 4, 8 and 12 wt.% of 40 to 60 micron-sized SiC particles were investigated in this study. The melt stir process was used to make composites comprising 8 and 12% SiC particles in the Al2014 alloy. To increase the wettability between Al matrix SiC particles, SiC particles were warmed to 300 degrees Celsius before being disseminated into the Al2014 alloy matrix in two phases. SEM, EDS were used to examine the specimens microstructurally. ASTM standards were used to evaluate the mechanical characteristics of micro SiC particles reinforced Al alloy composites with a content of 4 to 16%. SEM and EDS microstructural tests revealed the existence and dissemination of micro SiC particles in the Al2014 matrix. The addition of 8 and 16% weight % of micro SiC particles to Al2014 alloy improved. Furthermore, the presence of SiC particles reduced the ductility of Al2014 alloy. SEM microphotographs were used to examine the manufactured Al2014 with SiC composites for tensile fracture analysis, revealing the various mechanisms intricate in tensile fracture.

**KEYWORDS:** Aluminum alloy, SiC, Composites, Universal testing

## I. INTRODUCTION

A composite material can be defined as a combination of more than one identifiable constituent intentionally combined to obtain homogeneous structures with better properties than individual used alone [1, 2]. In contrast to metallic alloys, the constituents of the composites retain their mechanical, physical, and chemical properties. The strength and stiffness of the composite is provided by the reinforcing phase. In most of the cases, the reinforcement employed in composites is stronger, stiffer, and harder than the matrix and it can be in the form of a fibre or a particulate [3, 4]. The dimensions of the particulates used in composites are more or less equal in all the directions. Particulates may be of spherical, platelets, or of any other regular or irregular geometry. Continuous fibre composites tend to be much stronger and stiffer than particulate composites. Because of the difficulties in processing and increasing brittleness, particulate composites contain less reinforcement which makes them much cheaper and are referred as discontinuously reinforced MMCs [5, 6]. Further, particulate-reinforced composites are isotropic in nature when compared to fibre-reinforced composites and offer higher ductility which makes them an attractive alternate to the conventional metals. From a practical point of view, chemical compatibility among the matrix and reinforcement is of high significance. It is required to retain the separate identity of the matrix and reinforcement during their exposure to extreme processing temperatures and applications [7]. To achieve thermal compatibility, understanding and controlling of extensive chemical reactions between the reinforcement and matrix within a bound are necessary. Nonthermal compatibility between them results in degradation of mechanical and thermal properties. During cooling of composites from their processing and forming temperatures, due to the large difference in coefficient of thermal expansion between the matrix and reinforcement, residual stresses and deformations gets introduced. These residual stresses and deformations can also be introduced during their applications at higher temperatures which could be deleterious. Both strength and stiffness also depend on the type of reinforcing element and their orientation in the matrix [8]. Continuous fibres possess large aspect ratios and normally have a preferred orientation. On the other hand, discontinuous fibres have small aspect ratios and generally oriented in random directions. Out of all the properties, the directionality is possibly the prime characteristic that differentiates the fibre-reinforced composites from the conventional metals/particulate composites.

## II. EXPERIMENTAL WORK

A. Materials Used. Al2014 is a wrought alloy with copper as the principal alloying element, which has a melting point of 660°C and a density of 2.80 g/cm<sup>3</sup>. The Al2014 alloy is primarily used in aerospace and transportation applications. Al2014 offers excellent toughness, corrosion resistance, and higher temperature strength, as well as a strong self-healing capacity throughout the welding process. Table 1 displays the chemistry of Al2014.

B.

C. The silicon carbide reinforcing material from Bioaid Scientific Industries Ltd., Bangalore, is 150 to 160 μm in size. The reinforcement material is black in hue. The density of the reinforcement particle is 3.10 g/cm<sup>3</sup> [23], with a melting point of 3200°C and a hardness of 3100–3150 kg/mm<sup>2</sup>. The SEM and EDS of SiC utilized to make the composites are shown in Figures 1 and 2.

Table 1: Elemental composition of Al2014

Elements	Si	Fe	Cu	Mg	Zr	Zn	Cr	Mn	Al
Weight (%)	0.7	0.5	5.0	0.3	0.20	0.1	0.10	0.4	Bal

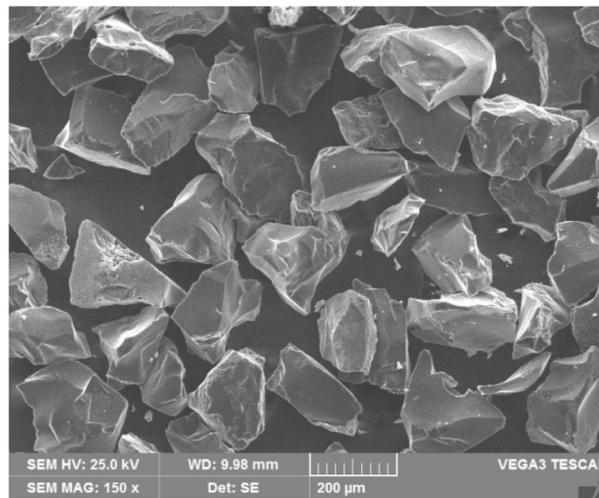


Figure 1: SEM micrograph of SiC particles

## III. METHODOLOGY

The fabrication of Al60-SiC composites will be carried out by liquid metallurgy route via stir casting technique. The major components of the casting process consist of electrical resistance furnace; zirconium coated steel impeller and cast iron permanent mould. The power rating of electrical furnace will be 60kw and maximum temperature limit is 1200 degree Celsius. The mechanical stirrer used for stirring the molten alloy during the preparation of composites with high temperature and to prevent migration of ferrous ions from the stirrer material into Al2014 alloy melts.

Calculated amount of the Al2014 alloy ingots are charged into the furnace for melting. The melting point of Aluminium alloy is 660 °C. The melt superheated to a temperature of 750 °C. The temperature will be recorded using achrome-alumel thermocouple. The molten metal is then degassed using solid hexachloroethane (C<sub>2</sub>Cl<sub>6</sub>) for 3 min. A stainless steel impeller coated with zirconium is used to stir the molten metal to create a vortex. The stirrer will be rotated at a speed of 300rpm and the depth of immersion of the impeller was 60 percent of the height of the molten metal from the surface of the melt. Further, the SiC particulates are preheated in a furnace upto 300°C will be introduced into the vortex. Stirring is continued until interface interactions between the reinforcement particulates and the matrix promotes wetting. Then, Al2014- 2,4 and 8 wt. % SiC mixture are poured into permanent cast iron mold having dimensions 125mm length and 15mm diameter.

The micro structural study was carried out on the investigating composites using scanning electron microscope and EDS. Samples around 15 mm diameter cut from the castings and are polished properly. Keller's reagent is used to

etch the samples. Further, based on the microstructural study compression, fatigue and wear properties are evaluated as per ASTM standards.

#### IV. EXPERIMENTAL RESULTS

##### Ultimate Tensile and Yield Strength

The effect of SiC particles on the strength of Al2014 alloy. The strength of the Al2014 alloy has increased as the weight percent of SiC increases in the soft Al matrix as shown. The Al2014 alloy’s ultimate tensile strength is 194.4 MPa. In addition, the UTS of Al2014-5 wt. % SiC and Al2014-10 wt. % SiC composites are 224.5 MPa and 262.4 MPa, respectively. After incorporating 10% weight percent of 40 to 60 micron-sized SiC particles into Al2014 alloy, the UTS improved. the effect of SiC content on the yield strength of the Al2014 alloy. The strength of the Al2014 alloy has increased as the weight percent of SiC content increases.

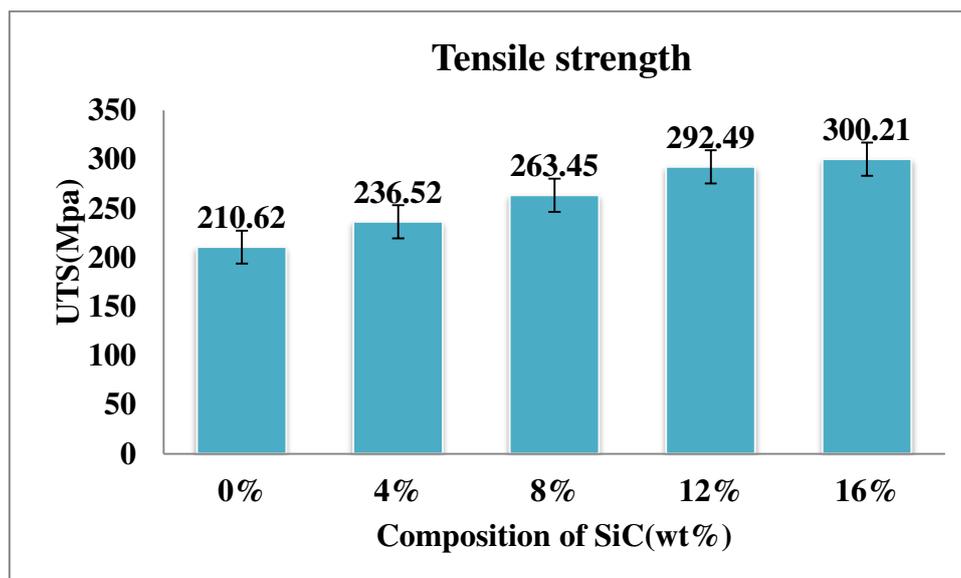


Figure shows Tensile testing sample

Table 1: Shows the tensile result

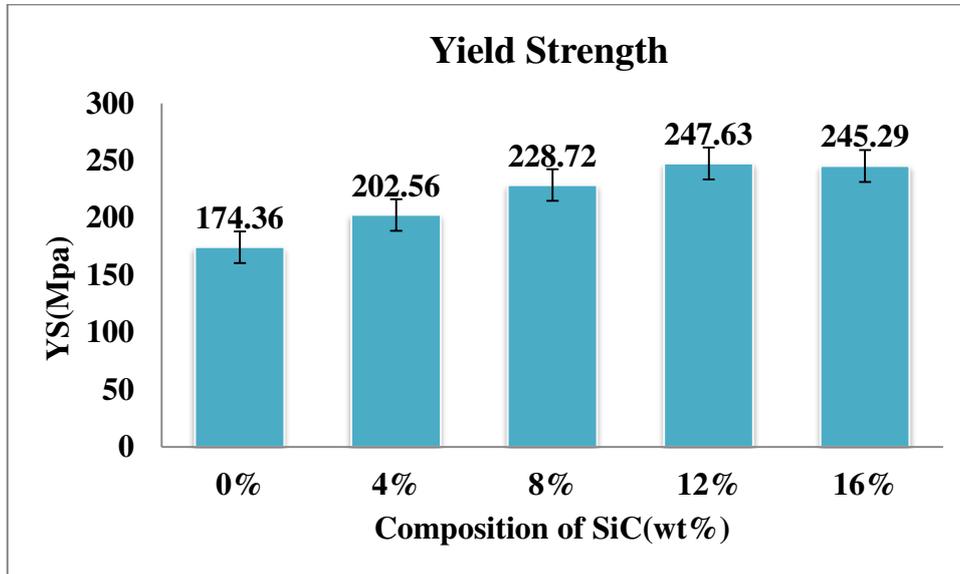
Sl. No.	Sample	UTS (MPa)	YS (MPa)	% Elong
1	Al2014 Alloy	201.62	174.36	11.51
2	Al2014-4% SiC	236.52	202.56	10.16
3	Al2014-8% SiC	263.45	228.72	9.01
4	Al2014-12% SiC	292.49	247.63	6.26
5	Al2014-16% SiC	300.21	245.29	8.10

##### Ultimate Tensile Strength



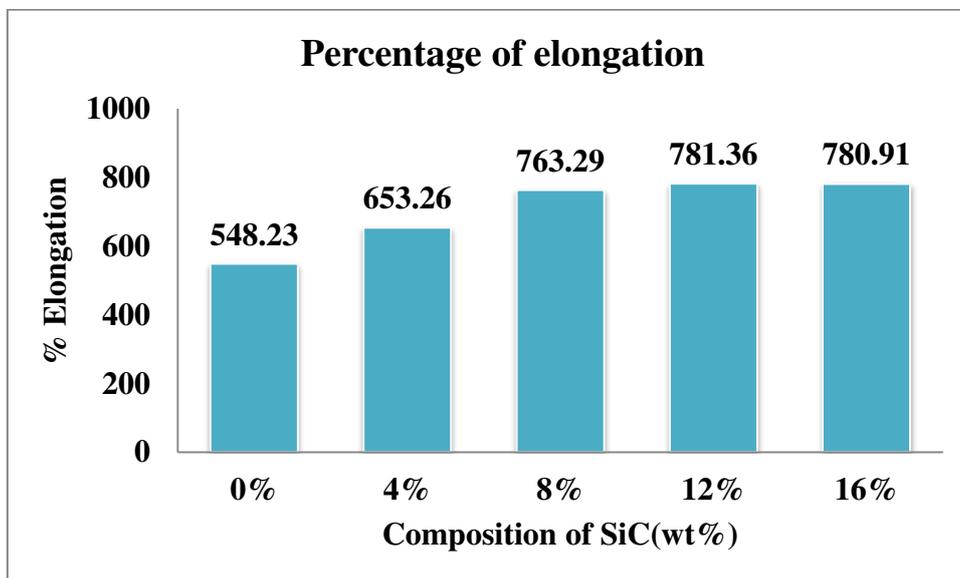
Graph1: showing the variations in ultimate tensile strength of Al2014 before and after addition of different wt. % of SiC particulate

Yield Strength



Graph2: showing the variations in Yield strength of Al2014 before and after addition of different wt. % of SiC particulate

Percentage Of Elongation



Graph3: showing the variations in % of Elongation of Al2014 before and after addition of different wt. % of SiC particulate

COMPRESSION STRENGTH

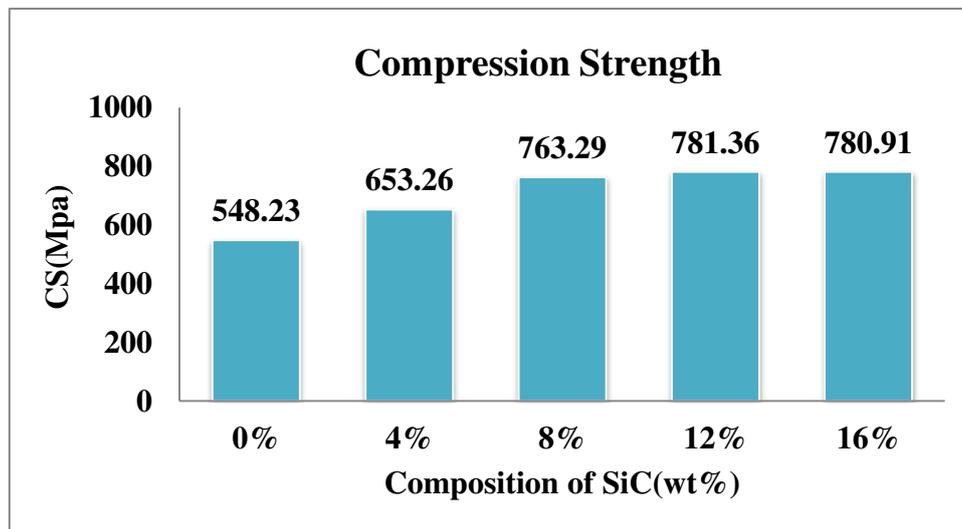
A majority of parts of structures, machines or devices are invariably subjected to uniaxial compression load. The behaviour of a material under simple uniaxial compression is called compression behaviour. The test performed for this purpose is referred to as compression test.

Among the various mechanical testing, compression testing is one of the most important and widely used. One can obtain important information concerning the material's ductile properties, the character and extent of plastic deformation, ultimate strength and toughness. The response of materials to other type of loading can sometimes be

explained or predicted on the basis of their behavior under simple compression. So much information can be obtained from a single test justifies its extensive use not only in engineering materials research but also in engineering industries for quality control and design purpose. Different materials respond differently to uniaxial compressive forces. The compressive curves correspond to these responses have discussed in below:

Table2: Shows the Compression results

Sl. No.	Sample	CS (MPa)
1	Al2014 Alloy	548.80
2	Al2014-4% SiC	653.26
3	Al2014-8% SiC	763.29
4	Al2014-12% SiC	781.36
5	Al2014-16% SiC	780.91



Graph4: showing the variations in Compression strength of 2014Al before and after addition of different wt. % of SiC particulate

The compression strength of Al2014 alloy and various wt. % of SiC composites. From the graph as weight percentage of SiC reinforcement increases from 4 to 16 wt. %, This increase compression strength is mainly due to high compression strength of SiC particulates. The compression strength of Al2014 alloy increased from 653.26MPa to 780.91MPa by adding 16 wt. % of SiC particulates in the matrix.

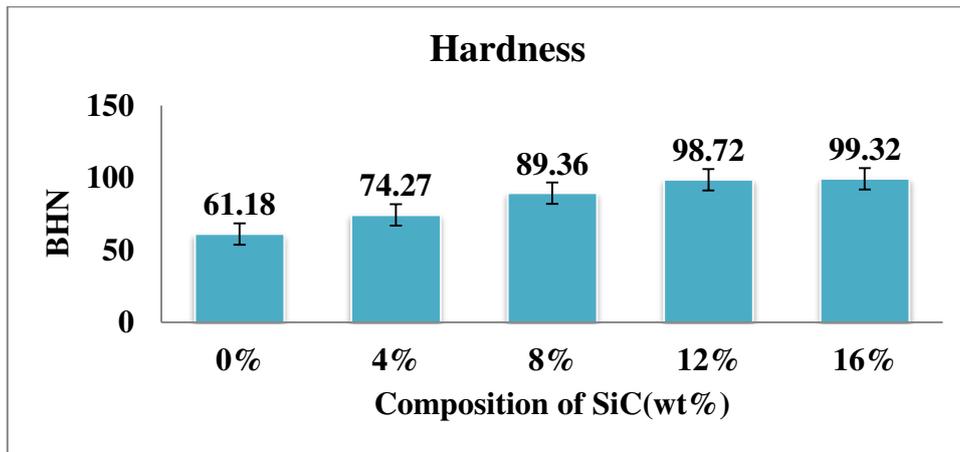
- Hardness Strength



Figure shows Hardness measurement sample

TABLE 3: Shows the hardness results

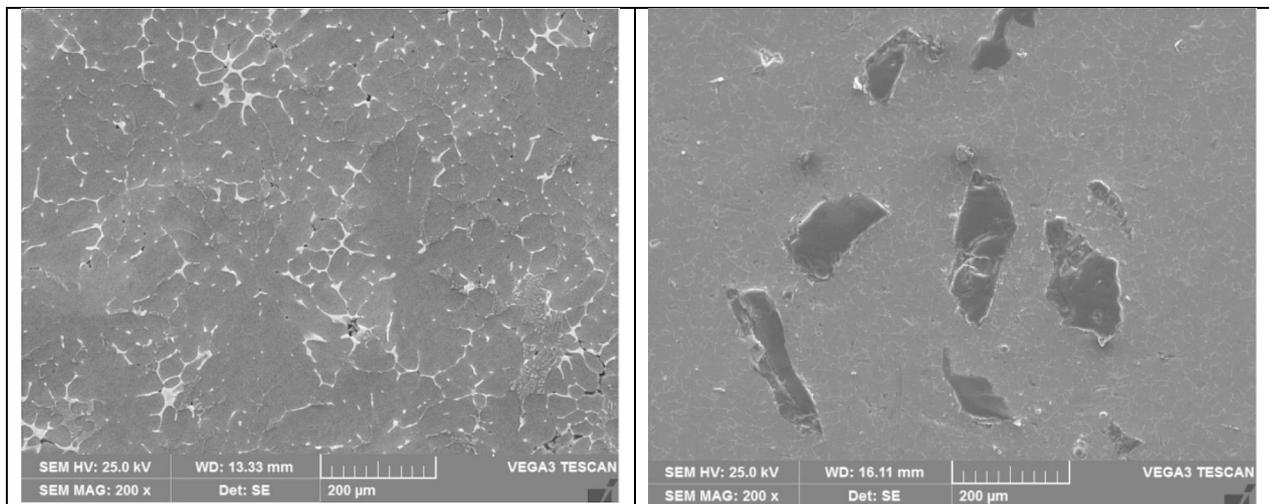
Sl. No.	Sample	BHN
1	Al2014 Alloy	61.18
2	Al2014-4% SiC	74.27
3	Al2014-8% SiC	89.36
4	Al2014-12% SiC	98.72
5	Al2014-16% SiC	99.32



Graph5: showing the variations in BHN of 2014Al before and after addition of different wt. % of SiC particulate

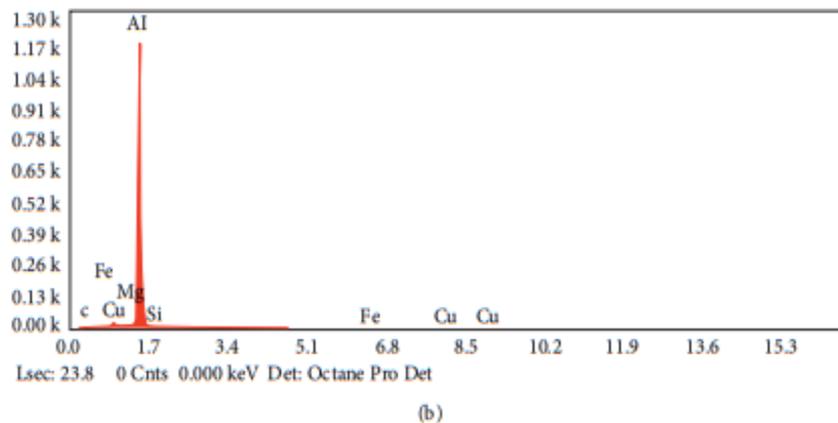
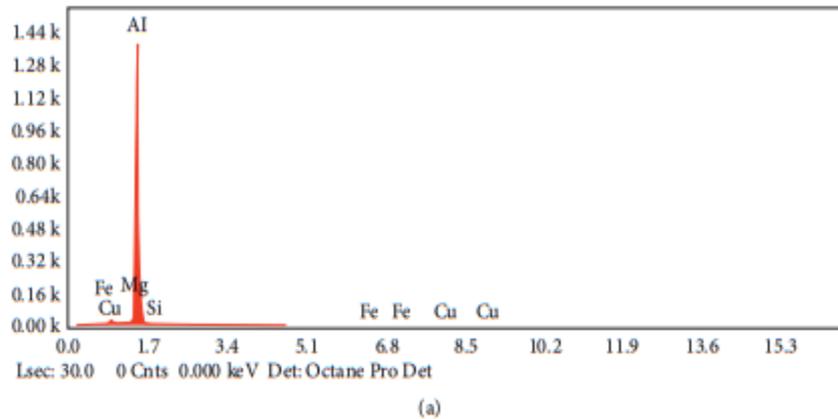
the hardness of Al2014 alloy, Al2014-4,8,12 and 16 wt. % of SiC composites. The plot shows that the hardness of Al2014 increases when the percentage of SiC particles increases from 4 to 16%. The hardness of the alloy as cast is 61.18 BHN, while it is 89.36 BHN and 99.32 BHN after including 8 and 16 wt. percent SiC, respectively. So incorporating such a high-hardness substantial into a soft Al material helps to improve hardness. Furthermore, the dislocation density is created by the thermal co-efficient mismatch among the Al2014 alloy and SiC particles, resulting in greater strain hardening in the composites. The composites hardness is increased through the strain hardening phenomenon. Basically reinforcements are more rigid and stronger than the Al2014 alloy matrix and these strength- ening particles always try to avoid plastic deformation.

• SCANNING ELECTRON MICROSCOPE MICROGRAPHS



For both the composite rods, the microstructure shows the grain boundaries, interdendritic network of SiC particles distributed in a matrix of aluminium solid solution throughout the structure. The composite reinforced with SiC in also presents a microstructure without porosity with uniform distribution of the reinforcing phase (SiC) and without the presence of agglomerations

- ENERGY DISPERSIVE SPECTROSCOPY (EDS)



The EDS spectra of Al2014 alloy with 16% SiC particles composites are shown in Figure 7(a) and 7(b). Cu is the predominant alloying element in Al2014 alloy, which also comprises Si, Fe, and Mg, as shown in Figure 7(a). The EDS spectrum of Al2014-12wt. percent SiC particles composites is also shown in Figure 7(b). The attendance of SiC in the Al2014 in the form of Si and C elements was visible in the EDS spectrum of composites. The existence of Si and C elements, as well as Cu, Mg and Fe elements, validates the integrity of the composites casting approach.

## V. CONCLUSION

The AMMC with different Weight fraction of SiC is fabricated and various investigations were made.

- Hardness values of the components were found and the hardness of the component increases with the increase in SiC percentage.
- Tensile strength has been increased at 4 and 12 wt.% of SiC, but when the percentage of SiC is increased further to 16 wt.%, the tensile strength is decreased.
- The microstructure shows the grain boundaries, interdendritic network of aluminium oxide and SiC particles distributed in a matrix of aluminium solid solution throughout the structure.
- There is increase in compression strength with addition of 8 and 12 wt% SiC particulates to base Al2014 alloy.

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