Investigation of microstructural, tensile and hardness characteristics of Aluminium 2024 alloy based Metal Matrix Composites

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Abstract - In this present investigation, efforts are made to study the micro structure, tensile strength and hardness of Al2024 composites with SiC / TiC particulates reinforced. The vortex method of stir casting was employed, in which the reinforcements were introduced into the vortex created by the molten metal by means of mechanical stirrer. Castings were machined to the ASTM standards on a highly sophisticated lathe. The samples were subjected to microstructural study, tensile and hardness tests. The degree of improvement of tensile strength and hardness characteristics of MMCs is strongly dependent on the kind of reinforcement. An improved tensile strength and hardness characteristics occurs on reinforced compared to unreinforced MMCs alloys.

Key words: MMCs, Al 2024 matrix, Microstructure, Tensile strength, Hardness.

I. INTRODUCTION

In the present days much attention has been focused on Metal Matrix Composites (MMCs) mainly due to their superior properties. Aluminium based metal matrix composites (AMMCs) have good mechanical and physical properties and hence they are used in various applications [1]. AMMCs have low density, improved stiffness, high strength and improved high temperature properties [2]. Because of their superior properties, they are extensively applied in the field of aircraft, spacecrafts, automobiles with the parts such as engine piston, electronic packaging, brake drums and so on [3]The wear resistance, hardness abrasive property, strength to weight ratio and thermal properties of AMMCs can be further improved by the reinforcement of hard particles like ceramics.The unique properties of the particulate reinforced composite materials are to a great extent dependent on the unique nature on the matrix-particle interface. The most common material reinforcements are Al2O3and SiC [4].The improvement in the mechanical properties are influenced by the type of the particle, morphology, size, volume fraction and distribution of the reinforcing particles in the base metal matrix[5]. When hard ceramic particles are added to soft Aluminium alloys, it enhances the wear strength and wear resistance [6].Reinforcement disbursement should be uniform throughout the composite material in order to achieve high strength which, otherwise leads to lower strength, lower ductility and toughness due to clusters of reinforcement [7].The grain size and the percentage of reinforcement influences in selection of the fabrication method of the composite.

AMMCs are produced using stir casting method , Friction stir processing and powder metallurgy techniques[8].Out of all the processes, stir casting process is the most economical and effective method to produce particulate reinforced metal matrix composites. Mechanical stirring in the furnace is the key element in stir casting process to get the dispersion of ceramic particles and sufficient wetting of the particles by the liquid metal [9].The distribution of ceramic particles depends upon the geometry of stirrer, speed of the stirrer placement of stirrer in the furnace and melt temperature in furnace[10]

After extensive literature survey, it is observed that the improvement in tensile strength and wear properties of Aluminium based metal matrix composites are resulted with the addition of different weight percentages of reinforcements, their grain size, shape, different fabrication methods [11-14]. From previous investigations it is observed that SiC with Flyash reinforced Aluminium hybrid composites exhibits better mechanical properties with lower density and porosity level compared to unreinforced Aluminium composites [15-17].

Cao Fenghong et. Al Studied that the hardness of hybrid composite of Al 6061/SiC/WC composite has been increased due to the incorporation of stiffer and stronger reinforcement in the matrix material [18].It is generally observed the addition of ceramic particles in different proportions improves different mechanical thermal and tribological properties of base Aluminium matrix[19-20].

The main objective of this project is to develop Al (2024)-Silicon carbide/Titanium carbide particulate metal matrix composites. The silicon carbide/ Titanium Carbide is used as the reinforcement & Al 2024 is used as matrix material. Different weight percentage of composite specimens areprepared by using liquid route metallurgy technique. Test specimens are prepared and are evaluated for their tensile and hardness characteristics.

II. EXPERIMENTATION

2.1 Selection of material

The matrix material Al 2024, reinforcement material SiC30-40 µm size particles /TiC 30-40 µm are used for the development of MMCs. The chemical composition of Al2024 is as shown in the Table 1.

Table 1: Al 2024 Chemical composition

Element	Copper	Magnesium	Manganese	Iron	Silicon	Chromium	Zinc	Aluminum
Weight percentage (Wt%)	4.3	1.3	0.4	0.4	0.3	0.1	0.3	93

2.2 Preparation of Composite

The SiC/TiC of 30-40 µm size were used as the reinforcement and the reinforcement content in the composites was varied from 0% to 8% in steps of 2% by weight. Liquid metallurgical technique was used to prepare the composite materials in which the SiC/TiC particles were added to the molten pool through a vortex created due to continuous stirring using an alumina coated stainless steel stirrer. Zirconium coated stirrer was also used to stir the molten metal. The pre-heated (7730K) SiC/TiC particles were added into the vortex of the liquid melt. The resulting mixture was poured by tilting the same in to the preheated permanent moulds. Figure 1 and 2 shows the stir casting process and casings respectively.

Figure:1 Stir casting equipment

Figure :2Castings

2.3. Study of microstructure

Examination of micro structure of prepared composites was done using scanning electron microscope to study and analyze the microstructure. A section of the castings was taken and were polished with different grades of emery papers. The samples were examined under scanning electron microscope.

2.4. Tensile test

Tensile tests were carried out at room temperature as per ASTM E8. The geometry of tensile test specimen is shown in Fig. 2.3. The prepared tensile test specimens are shown in Fig. 2.4. The test uses specimens of 20 mm grip diameter, 30 mm grip length, 62.5 mm gauge length, 75 mm length of reduced cross section, inner diameter of 12.5 mm fillet radius of 10mm and total length 155 mm were machined from those cast composites for the gauge length of the sample parallel of the longitudinal axis of the castings. The figure 3 shows the machined test specimens.

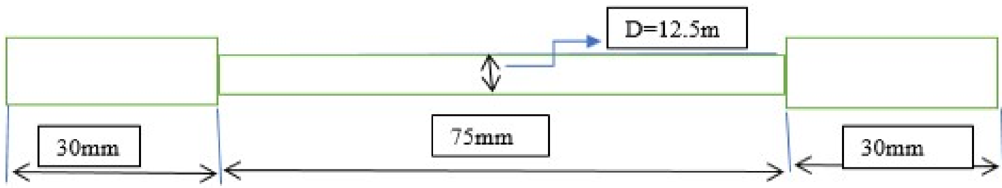


Figure: 3 Geometry of tensile test specimen

Figure: 4 Prepared Tensile specimens as per ASTM E8standard.

2.5. Hardness test

Brinell hardness test was performed by indenting a hard steel or carbide sphere of a specific diameter under a specific load into the surface of a material and measuring the diameter of the indentation left after the test. The Brinell Hardness Number (BHN) is calculated using the following formula. Figure 5 shows the specimens after Brinell hardness test.

$$BHN = \frac{F}{\frac{\pi}{2} D * (D - \sqrt{D^2 - Di^2})}$$

Where,

BHN = Brinell Hardness Number

F = Applied load in kg

D = Diameter of the spherical indenter in mm

Di = Diameter of the resulting indentation in mm

Fig.2.5 shows the hardness samples with indentation

Figure: 5Specimens after conducting Brinell's test

III Results And Discussion

3.1 Microstructural Characterization

The SEM micrographs of Al 2024, Al2024+2 wt. % of SiC,Al2024 + 4 wt. % of SiC, Al2024 +6 wt. % of SiC and Al7075+8 wt. % of SiC are shown in Figure 6.In Al2024+2 wt. % of SiC sample, there is a uniform distribution of SiC ceramic particles in the Aluminum alloy base matrix in the form of grains. The grain formation patterns could be due to the orientation of reinforcements into the matrix caused by the stirring process, the density and other factors that influence the settlement of the reinforcement particles into the matrix material. In Al2024 + 4 wt. % of SiC sample the dispersion of the SiC particles are reasonably homogenous, while the formations of the grain patterns are comparatively finer. The micrograph of Al2024 +6 wt. % of SiC shows uniform distribution of the SiC particles in the Aluminium alloy matrix and refined grain structure is observed. In the micrograph of Al2024+8 wt. % of SiC.one can observe random grain orientation with clustering spots of ceramic particles which could be due to an increase in the weight percentage of silicon carbide/Titanium Carbide particles.The reinforcement particles are uniformly distributed by stirring process where dendrite shaped structure breaks into equiaxed form. This improves the wettability and incorporation of the particles within the melt. This method enables dispersion of reinforcement particles more uniformly in the matrix.

Figure 7 shows the SEM micrographs of Al 2024 with 2, 4, 6 and 8% by weight of Titanium carbide reinforcement. SEM micrographs shows the uniform distribution of Titanium carbide particles in the samples. The micrographs of 4 wt% and 6 wt% Titanium Carbide shows uniform distribution of the reinforced particles as well as agglomeration of particles at few places.

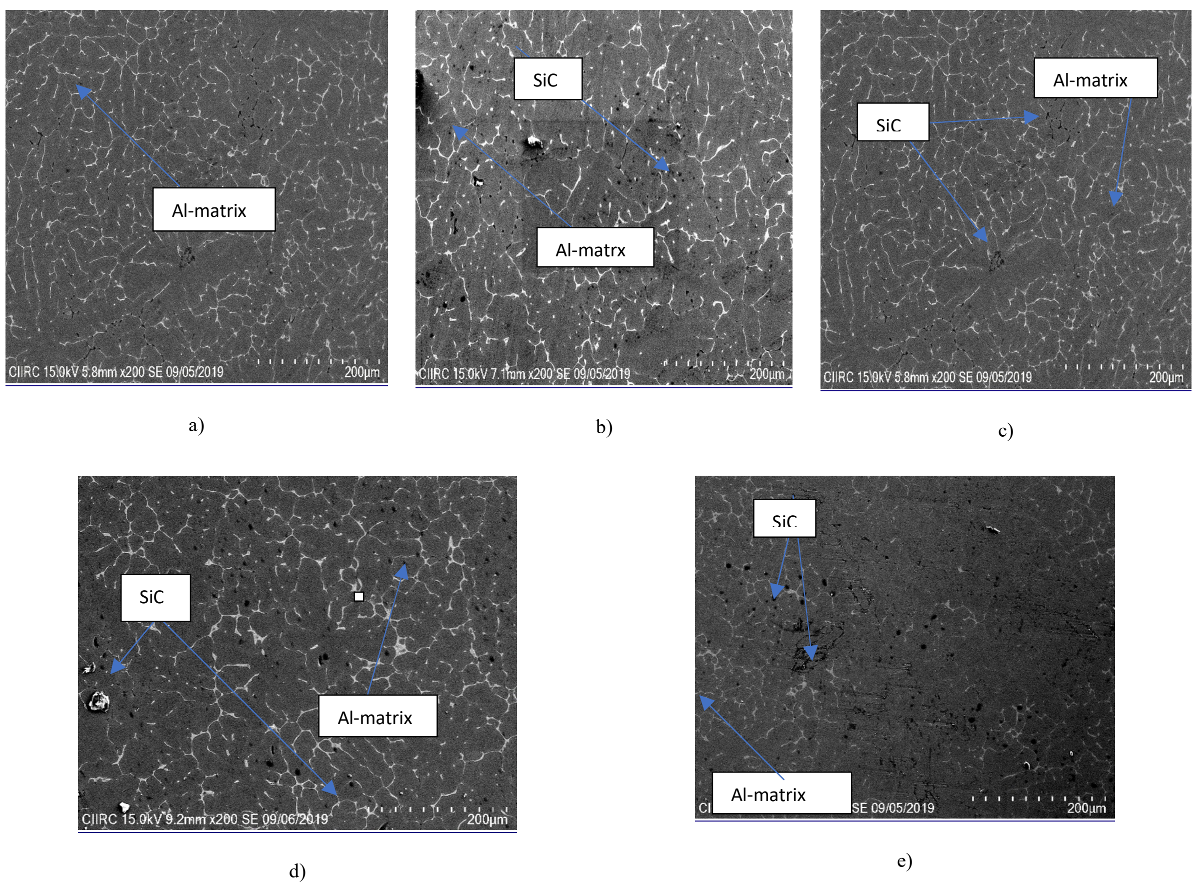
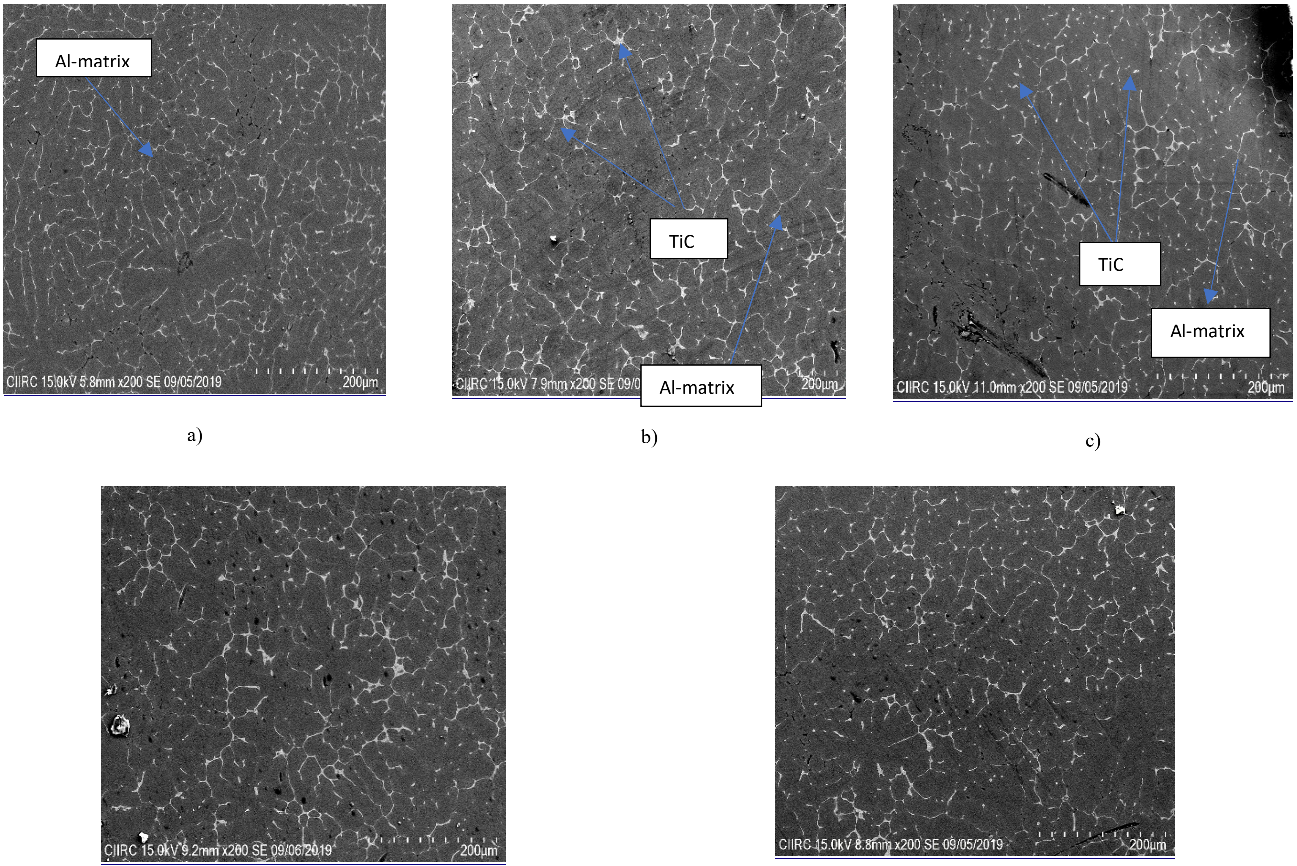


Figure: 6SEM micrographs of Al 2024 alloy -SiC compositea) Al 2024+0% SiC AC , b) Al 2024+2% SiC AC, c) Al 2024+4% SiC AC, d) Al 2024+6% SiC AC, e) Al 2024+8% SiC AC



a) b) c)

d) e)

Figure 7 : SEM micrographs of Al 2024 alloy -TiC compositea) Al 2024+0% TiC ACb) Al 2024+2% TiC ACc) Al 2024+4% TiC AC

d) Al 2024+6% TiC ACe) Al 2024+8% TiC AC

3.2. Tensile properties

3.2.1 Effect of reinforcements on Ultimate Tensile Strength(UTS)

The variation of UTS with the percentage of reinforcement is shown in Figure 8.The reinforcing phase in the metal matrix composites has much higher stiffness than the matrix. The enhancement of elastic modulus and strength of the composites takes place due to the strong interface which transfers and distributes the load from the matrix to the reinforcement. The particle reinforced Al-MMCs possesses higher tensile strength than monolithic alloys. The tensile strength of the which is not reinforced is 185 N/mm^2 and this value increased to 210 N/mm^2 for Al/(6%SiC). In case of Al/TiC which makes the material stiffer than the Al-SiC particles, and the tensile strength increased to 217 N/mm^2.The main reason is Titanium Particles are distributed uniformly in composites and grain boundaries are very small, this in turn increases the strength of the composite.

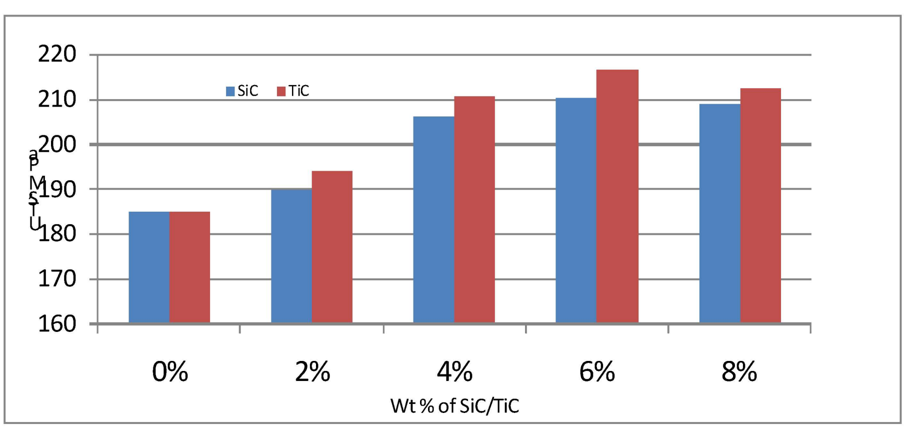


Figure 8 : Reinforcement effect on UTS

3.2.2 Effect of reinforcements on percentage elongation

Figure 9 depicts the graph of the experimental elongation of the composites with different percentage of reinforcement. From the graph, it is observed that the elongation of composites gradually reduced as compared to unreinforced aluminium. For unreinforced Al elongation is seen as 16%.

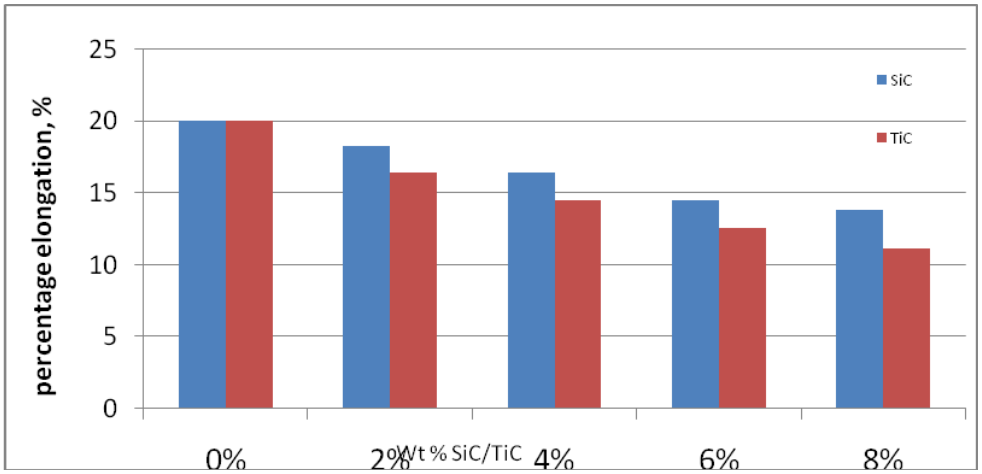


Figure 9: Reinforcement effect on percentage elongation

3.2.3Influence of reinforcements on yield strength

Figure 10 shows the effect of reinforcement on yield strength. From the graph it is observed that an increase in the content of SiC particulates from 0% to 2% in the base matrix causes increase in yield strength by an average of 12%. Further an increase in SiC particulates from 2% to 4% yields an increase in yield strength about 14.28%. With 4% to 6% increase in reinforcement will increase yield strength by 9.89%. Further increase of reinforcement from 6% to 8% caused a decrease in yield strength by 55.23%. This is mainly due to cluster formation of SiC particulates in the base matrix.

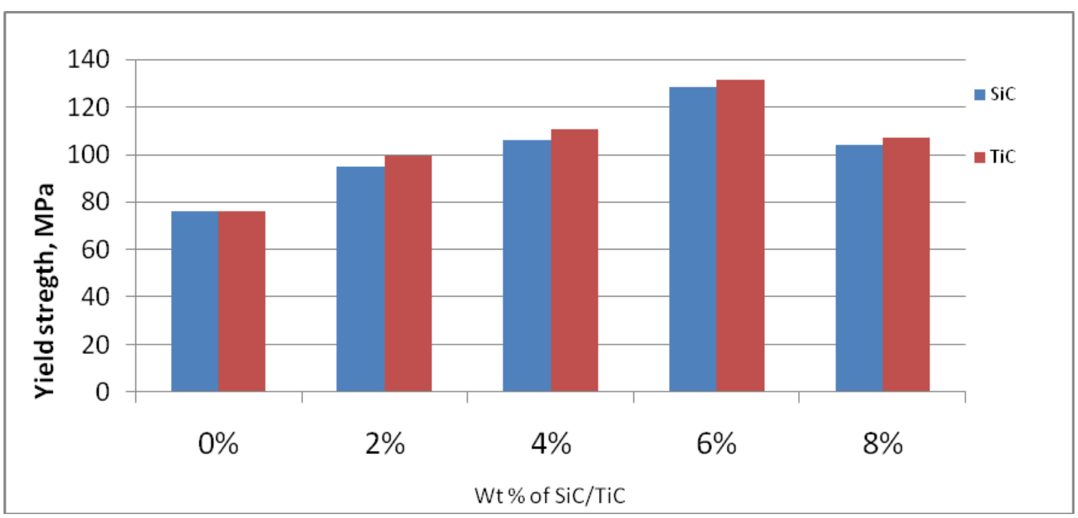


Figure 10: Reinforcement effect on yield strength

3.3 Hardness test results

Figure 11 shows the variation of BHN with percentage of reinforcement. It is noticed that an increase in the hardness with the increase in weight fraction of SiC/TiC. The maximum hardness is obtained for Al/(6%SiC/TiC) sample. Thus, in conclusion, the mechanical properties such as yield strength, tensile strength and hardness of the composite increases with the increase in the reinforcement of SiC/TiC.

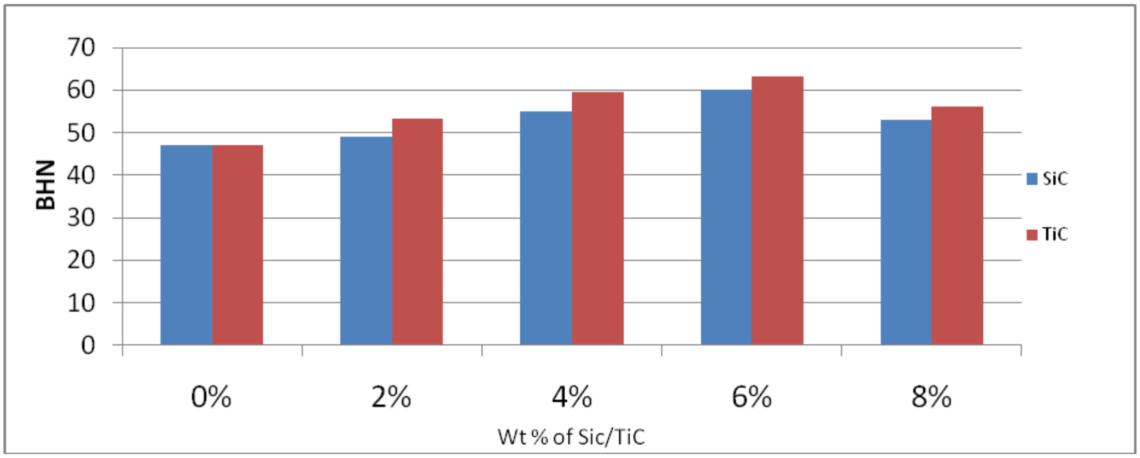


Figure 11:Reinforcement effect on hardness

IV CONCLUSIONS

1. Metal matrix composites with Aluminium 2024 as base matrix and reinforcement as SiC/TiC particles with various weight fraction were successfully synthesized by using stir casting method.

2. A remarkable improvement in micro hardness is noticed with increase in SiC/TiC particles in Al2024- SiC/TiC composite when compared with unreinforced alloy.

3. Though the ductility of the composites reduces with the addition of secondary particles in the aluminium alloy,however, Al2024 alloy have higher ductility when evaluated with the composites under all the compositions studied.

4. UTS of Al2024 alloy and Al2024- SiC/TiC composites increase with increase in reinforcement percentage.

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