

# Experimental investigation on mechanical behaviour of sand cast Al 6061-SiCp metal matrix composites

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## ABSTRACT

Al 6061-SiCp metal matrix composites were synthesized successfully using sand casting processes. The effects of volume fractions of reinforcements on the composite properties were investigated. Vortex method was used to add the reinforcement particles with the Al 6061 alloy. The sand mould was prepared to make the composite castings. The microstructural characterization studies revealed the uniform distribution of SiC particles in the aluminium matrix and particle clustering in some places. The results of mechanical characterization revealed that the density, hardness and impact energy of composites increased on increasing the volume fractions of SiC particles.

*Keywords:* Metal matrix composites; Vortex method; SiCp; Sand Casting

## 1. INTRODUCTION

In recent years, aluminium alloys are replaced by aluminium matrix composites in the automobile industry to improve the energy efficiency and environmental requirements. Aluminium matrix composites are known for their excellent physical and mechanical properties. This was because of the soft aluminium reinforced with hard and stiff ceramic particles. The structural aluminium alloys such as 6xxx and 7xxx series are the most commonly used matrix materials due to their low density and high thermal conductivity. The inexpensive ceramic reinforcements such as SiC and Al<sub>2</sub>O<sub>3</sub> fibres and particles are the most widely used reinforcements in metal matrix composites (Miracle DB, 2005).

There are several fabrication techniques available to produce aluminium matrix composites. The fabrication techniques are classified into three types. These are solid phase processes, liquid phase processes, and semi-solid processes. The liquid phase processes, in principle, similar to conventional casting route to be used (Kaczmar, 2000). Casting is the economical route to produce metal matrix composites because the composite melt is directly poured into the mould having required shape and size. Melt stirring process plays a major role in mixing of ceramic reinforcements with the metallic alloys to produce the metal matrix composites. This process is simple, economical, flexible and applicable to large-scale production (Hashim, 1999).

Akhil et al. (2014) studied the mechanical and microstructure properties of LM6 metal matrix composite with PbO glass reinforcement. The composites were produced using a sand casting technique. They investigated the variation in % composition, hardness, tensile strength and microstructure properties of composites. The tensile strength and hardness of the composite are increased with increasing the % of reinforcement. The microstructure revealed the formation of silicon dendrites and the dispersion of the glass particle. Kumar et al. (2015) used sand casting technique to develop fly ash reinforced aluminium metal matrix composites and investigated the hardness and tribological properties by varying the fly ash content. It has been reported that the hardness of composites is increased on increasing the fly ash content. In addition, the tribological properties such as wear rate and coefficient of friction increased and then decreased when the fly ash content was increased.

Sulaiman et al. (2008) studied the mechanical properties of quartz particulate reinforced LM6 alloy matrix composites. They reported that the tensile strength and young's modulus decreased and hardness increased when the volume fraction of reinforcement was increased. From the literature, it was observed that not much work has been reported on Al 6061-SiCp metal matrix composites, fabricated by sand casting technique. So, it is planned to produce Al 6061-SiCp composites using sand casting processes and investigate the effect of SiC particle content on mechanical properties of composites.

## 2. MATERIALS AND METHODS

Aluminium 6061 alloy with the theoretical density 2.7 g/cm<sup>3</sup> and SiC particle with the average particle size of 50 µm were selected as a matrix and reinforcement materials. Al 6061-SiCp metal matrix composites were prepared using sand casting process. The chemical composition of Al 6061 alloy and SiCp are given in Table 1 and 2. A predetermined quantity of matrix alloy in the form of ingots was placed in a graphite crucible and melted when the furnace temperature was raised to 800°C. Hexachloroethane tablet was used as a degassing agent, which removed the entrapped gasses and other impurities/slag from the molten metal. To improve the wettability of reinforcement with the matrix, SiC particles were oxidized in air at 800°C for 2 hours.

**Table.1. Chemical composition of Aluminium 6061 alloy**

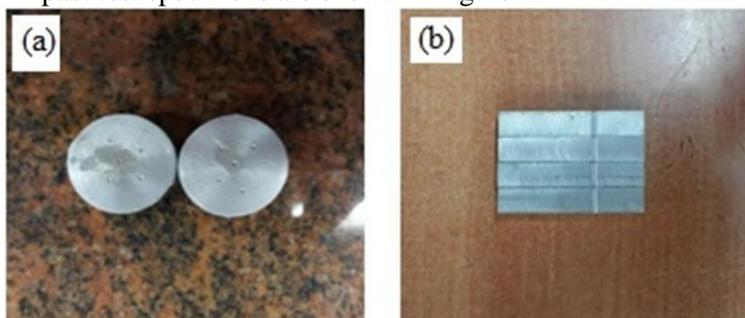
Elements	Mn	Cr	Fe	Cu	Si	Mg	Zn	Ti	Al
(wt.%)	0.01	0.05	0.17	0.33	0.71	1.12	0.1	0.01	Balance

**Table.2. Chemical composition of SiC particle**

Elements	SiC	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	Fe <sub>2</sub> O <sub>3</sub>	Free C	Others
(wt. %)	98.54	0.20	0.68	0.24	0.26	0.08

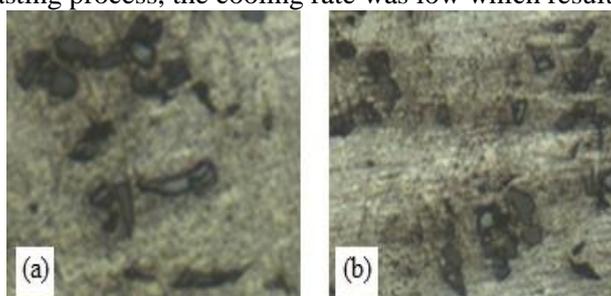
A mechanical stirrer, which is driven by a variable speed motor, was used to add the SiCp with molten Al 6061 alloy. The molten metal was stirred at a constant speed of 600 rpm to ensure homogeneous mixing of reinforcement particles. The oxidized SiC particles were incorporated into the molten metal in different volume fractions. Once the reinforcement addition was over, the stirring was extended for another few minutes. The composite melt was maintained at a temperature of 720°C. The sand casting process was used to prepare composite castings. The green sand mould was prepared using a pattern (shape of required casting) with a gating system. The mould was dried with the help of a heater to remove the moisture content. Then the mould cavity was filled with the composite melt, and it was allowed for solidification. After the solidification process, the sand mould was broken, and the casting was removed.

**Characterizations:** The castings were machined, and test specimens were prepared to the required size for various tests. The composite specimens were prepared using standard metallography procedures and microstructural characterization was performed on the specimen to investigate the distribution of SiC particles in Al 6061 alloy. Theoretical density of composites was calculated using Rule of mixture and experimental density measurements were carried out on the composite specimen using Archimedes principle. The hardness of composites was measured using Rockwell hardness tester to investigate the effect of SiC particles on the matrix alloy. The Izod impact test was performed using a V (45° and 2 mm deep) notched specimen having 75 mm length with a cross section of 10 mm X 10 mm. The hardness and impact test specimens are shown in Figure 1.

**Figure.1.(a) Hardness test specimen (b) Izod impact test specimen**

### 3. RESULTS AND DISCUSSION

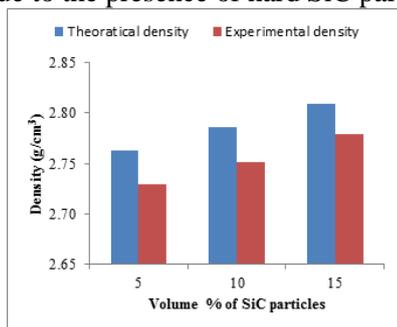
**Microstructure:** Figure 2 shows the optical micrograph of 10 vol. % of SiCp reinforced aluminium composite. From the Figure 2 (a), it was evident that SiC particles uniformly distributed in the aluminium alloy. Figure 2 (b) revealed that there was a particle clustering in some places, but strong interfacial bonding between the SiC particles and aluminium alloy. In the sand casting process, the cooling rate was low which resulted in particle clustering.

**Figure.2. Microstructure of 10 vol. % SiCp/Al 6061 composite**

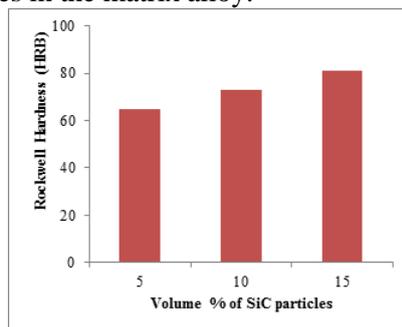
**Density:** The variation in density of composites with volume % of SiC particles is shown in Figure 3. The values of density in composites are increased by increasing the volume fraction of reinforcements. The matrix alloy and SiC particles have the densities of 2.7 and 3.2 g/cm<sup>3</sup> respectively. As the density of SiC particles was higher than Al 6061 alloy, the density of composites was improved. It was also noted that the experimental density of composites was lower than the theoretical density.

**Hardness:** Figure 4 shows the variation in hardness of composites with volume % of SiC particles. The addition of hard SiC particles into the soft Al 6061 alloy improved the hardness of composites. The hardness of composites is increased more or less linearly with the volume fraction of reinforcements in the Al alloy. This effect could be attributed to the presence of hard SiC particles, which increase the load-bearing capacity of the material and also restrict the matrix deformation by constraining dislocation movement.

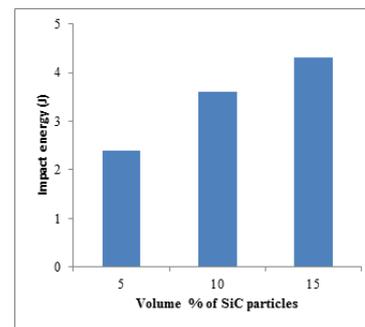
**Impact energy:** The variation in impact energy of composites with volume % of SiC particles is presented in Figure 5. The impact energy of composites increased linearly with the volume % of SiC particles in the Al alloy. This was due to the presence of hard SiC particles in the matrix alloy.



**Figure.3.Variation of density with volume % of SiC particles**



**Figure.4.Variation of hardness with volume % of SiC particles**



**Figure.5.Variation of impact energy with volume % of SiC particles**

#### 4. CONCLUSION

Al 6061-SiCp metal matrix composites were synthesized successfully using sand casting process. The following conclusion has been drawn:

1. Microstructure characterization revealed the uniform distribution of SiC particles and particle clustering in some places.
2. The values of density in composites are increased by increasing the volume fraction of reinforcements, but experimental density was lower than theoretical density.
3. The hardness and impact energy of composites increased linearly with the volume fraction of reinforcements in the Al alloy.

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