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Investigation of mechanical properties of Al 6063-SiC composites

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Abstract

In the present investigation, Aluminium (6063) is used as a metal matrix and silicon carbide particles are used as reinforcement. The AMCs of varying SiC contents (0, 3, 6 and 9 wt. %) were prepared by stir casting process. The tensile strength, % elongation and hardness of the fabricated composites were investigated. The experimental result reveals that, the addition of SiC reinforcement in the aluminium matrix increases the tensile strength and hardness, the % elongation of composite decreases as silicon carbide percentage increases.

Keywords: Aluminium; Al 6063; SiC; Tensile strength; Hardness

1. Introduction

Over the past few decades, researchers have emphasized on production of light and strong materials. This caused the scientists to shift their research from monolithic to composite materials. A composite material can be defined as a combination of a matrix and a reinforcement, which when combined gives properties superior to the properties of the individual components [1]. Matrix is the base material in the composite. Based on the type of matrix; composite materials are classified into metal-matrix composites, ceramic-matrix composites and polymer-matrix composites. In metal matrix composites, aluminium and its alloys have attracted most attention as base metal in metal matrix composites because of its low density, low weight, easy machining, high strength, superior malleability, excellent corrosion resistance and good electrical and thermal conductivity. The further enhancement in properties can be achieved by the addition of various types of reinforcements. Generally, aluminium is reinforced with ceramics such as B_4C, TiC, AlN, TiB_2, TiO_2, SiC and Al_2O_3 particulates. Fabrication of aluminium matrix composites can be accomplished by different techniques viz. stir casting, infiltration processes, squeeze casting, reactive in situ technique, powder metallurgy and friction stir processing (FSP). Manufacturing of aluminium composite by stir casting is one of the most economical methods of processing metal matrix composites. The properties of AMMCs are mainly depending on micro structural parameters of the reinforcing materials such as size, shape, orientation and volume fraction.

2. Literature review

N.R. Rajasekaran et al [2] fabricated and investigated the effect of reinforcement on the mechanical properties of aluminium metal matrix composite. In this work two different sample were fabricated by changing the quantity of TiB_2 i.e. (5% and 10%). The result of this test showed that the tensile strength, yield strength and hardness increases with the increase in TiB_2 percentage, whereas percentage elongation decreases with the increase in TiB_2 percentage.

V. Hari Kumar et al [3] created aluminum-TiC composite and researched its mechanical properties. Aluminum is selected as the matrix material and titanium carbide as reinforced particulates are mixed in different weight percentages (8, 16, 24, and 32 wt %). The test samples were prepared as per ASTM standards to investigate mechanical properties viz. Hardness, flexural strength and impact strength. From the experimental results it is inferred that,

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increases in hardness and impact strength was observed with increase in particulate phase up to 24% by wt, there after decreased. There is a little change in flexural strength was observed with the addition of TiC particulate phase in pure aluminum.

Mahesh L et al [4] fabricated Al-TiO_2 composite and investigated its mechanical properties. The aluminum - TiO_2 composites were fabricated by using powder metallurgy process with different particulate weight fractions (5, 10 and 15%). The effect of reinforcement on the density, porosity, hardness, strength and microstructure of composites was investigated. The authors have revealed that the density, porosity, hardness and compressive strength of Al-TiO_2 composites were found to increase with increase in the weight % TiO_2 from 5 to 15 weight percent.

Krishna Chandra Patra et al [5] developed WC reinforced aluminium composites and analyzed its mechanical properties. The composites were prepared by adding 0, 5, 10, 15 and 20 wt. %. of nano WC by liquid metallurgy technique. The analysis shows that the hardness, ultimate tensile strength, compression strength and young's modulus were found higher than those of control alloy.

Dr. Sumathy Muniamuthu et al [6] developed the Al_2O_3 reinforced AMCs and study the effect of reinforcements on the mechanical properties. In the present case, the Al_2O_3 content is varying in composition of (2, 4, 6 and 8 wt %) in aluminum matrix, fabricated by stir casting technique. They observed that the tensile strength, impact strength and hardness of the composite increases as weight fractions of the Al_2O_3 particles increases.

B. Ravi [7] studied the fabrication and mechanical properties of Al7075-SiC-TiC hybrid metal matrix composites. Al7075 alloy was selected as matrix alloy and silicon carbide (SiC) and titanium carbide (TiC) were used as reinforcements for fabrication of HMMCs by liquid metallurgical technique. The mechanical properties such as yield strength, ultimate tensile strength, hardness and impact strength were conducted for HMMCs specimen as per ASTM standard. The authors reported that the mechanical properties are increased for the combination of reinforcement TiC and SiC and impact strength was decreased.

Sachin Mohal et al [8] investigated on mechanical properties of Al6061/Al_2O_3-SiC composites. The weight percentages of Al_2O_3 have been varied from 3% to 9%, whereas SiC has been kept constant at 6% for all the samples. After successful fabrication of Al6061/Al_2O_3-SiC composite, tensile strength, percentage elongation and micro hardness have been analyzed. The results showed that the tensile strength increases with the increase in Al_2O_3 percentage, whereas percentage elongation decreases with the increase in Al_2O_3 percentage. Micro-hardness increases up to 6% Al_2O_3 and then starts decreasing.

Sunil Kumar Tiwari et al [9] fabricated a metal matrix composite using B_4C particles in Al7075 alloy using stir casting process. Three samples with different weight% of B_4C have been fabricated as Al-2.5wt% B_4C, Al-5wt% B_4C and Al-0wt% B_4C. Cast samples were prepared for mechanical characterization namely tensile testing and hardness testing. Results of mechanical characterization showed that the tensile strength and hardness of the composite increased with increase in weight percent of reinforcement in the matrix.

Pravin Vyavahare et al [10] investigated on mechanical characterization of Al 356-B_4C composite. The boron carbide particle weight fractions of 3, 6,9, 12 % wt. of particle sizes 53-106 μm were reinforced into matrix material. The researchers observed that the tensile strength, compressive strength and hardness of the metal matrix composite increases as weight fractions of the B_4C particles increases.

3. Material and methods

3.1. Aluminium 6063

The Aluminium 6063 is an alloy with magnesium and silicon metals. Grade 6063 Aluminium is a medium strength alloy that is one of the most popular alloys in the 6000 series. It is used for window frames, door frames, roofs, electrical components, furniture, motor vehicles and pipe. The chemical composition of Al 6063 alloy is presented in table-1.

3.2. Silicon Carbide

Silicon carbide is a compound of silicon and carbon with chemical formula SiC also known as carborundum. It is highly wear resistant and also has good mechanical properties with low density, including high temperature strength and thermal shock resistance.

Table 1 Chemical composition for aluminium 6063

Elements	Minimum (% by weight)	Maximum (% by weight)
Aluminium (Al)	97.5%	99.35%
Magnesium (Mg)	0.45%	0.90%
Silicon (Si)	0.20%	0.60%
Iron (Fe)	0	0.35%
Chromium (Cr)	0	0.10%
Copper (Cu)	0	0.10%
Manganese (Mn)	0	0.10%
Titanium (Ti)	0	0.10%
Zinc (Zn)	0	0.10%
Others	0	0.15%

3.3. Composite preparation

The composites were prepared using the stir casting technique. We have fabricated four samples using different weight percent of SiC as Al-0wt% SiC, Al-3wt% SiC, Al-6wt% SiC, Al-9wt% SiC. The appropriate amount of aluminium alloy has been placed in crucible and left inside the muffle furnace until it melts completely. The reinforced particles size of SiC is varying between 37-74 microns. Silicon carbide particles were preheated at 800°C for about two hours. Preheated silicon carbide particles are then added into the crucible having molten matrix material. The reinforcement particles have been mixed by mechanical stirrer mounted on the top of the muffle furnace. The molten mixture has been superheated in muffle furnace which leads to increase in fluidity of alloy for pouring. Then the molten material is poured into cylindrical shape moulds with different dimensions.

3.4. Mechanical Testing

3.4.1. Tensile test

The tensile testing of the composites is done in a computerized universal testing machine. Four different composite specimens are made by varying the weight percentage of the reinforcement. The testing is done by placing the specimen between the jaws of the machine and tensile load is applied until fracture of the composite specimen occurs. This test is used to determine tensile strength and % elongation.

3.4.2. Hardness Test

Hardness measurement is done in vickers hardness testing machine. The vickers hardness test is a versatile hardness test method, used for both macro and micro hardness testing. The micro hardness test was carried in micro vickers hardness tester which has a testing load series of 10gms to 1 kg load and testing scale used is HV.

4. Results and discussion

Table 2 Mechanical properties of Al 6063-SiC composites

S.No	% of SiC	Tensile Strength (MPa)	% Elongation	Hardness
1	0	97.1	21.2	47.8
2	3	105.5	19.5	57.2
3	6	118.2	15.6	59.5
4	9	133.2	13.4	67.3

The prepared composite samples are investigated for their mechanical properties and are compared with the pure aluminium. The mechanical properties of the composite specimens are given in table-2.

4.1. Tensile strength

Figure-1 represents the variation in tensile strength of Al 6063-SiC composites with respect to weight percentage of SiC particles. From figure it can be observed that the tensile strength of the composites is higher than that of their base matrix also it can be observed that the increase in the silicon carbide content contributes in increasing the tensile strength of the composite. The properties of hard ceramic SiC particulates control the deformation of the composites. Due to the strong interface bonding, load from the matrix transfers to the reinforcement resulting in increased ultimate tensile strength. Manoj Kumar Gupta et al [11] investigated the mechanical and tribological characterizations Al1100 reinforced with TiB_2 particle composites. The composites are fabricated by reinforcing varying percentage (0, 2, 4, 6 and 8wt%) of TiB_2 in aluminium alloy Al 1100 through the stir casting process. The researchers observed that the tensile strength of the composite increased with increase in weight percent of reinforcement in the matrix. Madeva Nagaral et al [12] fabricated and investigated the effect of Al_2O_3 Particles on Mechanical and Wear Properties of 6061al Alloy Metal Matrix Composites. In this investigation, the fabrication of 6061Al composites with different weight percentage of Al_2O_3 particles up to 0-9% was processed by liquid metallurgy route. The result of this test showed that the tensile strength increases with the increase in Al_2O_3 percentage.

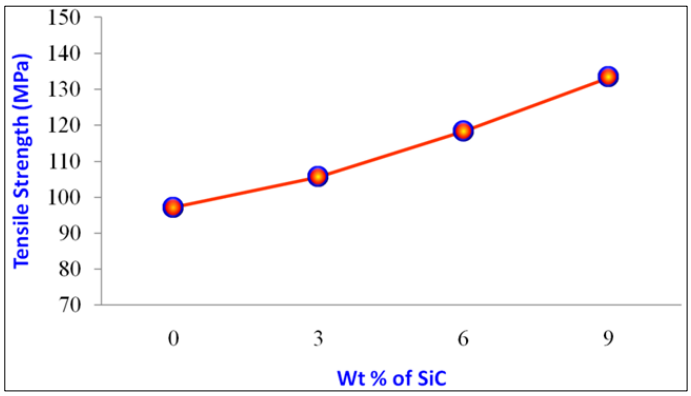

Figure 1 Tensile strength of Al 6063 alloy with SiC composites

4.2. Percentage elongation

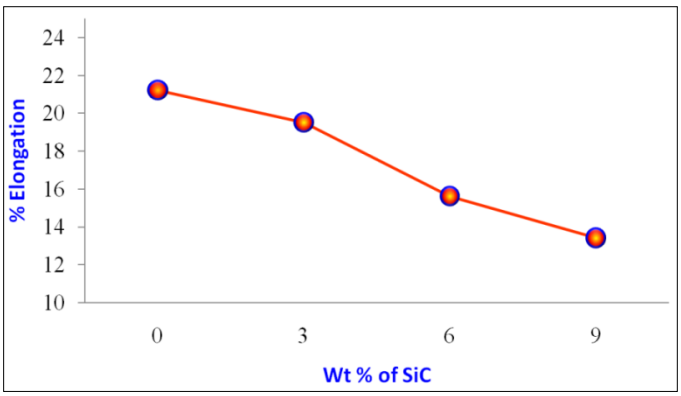

Figure 2 Percentage elongation of Al 6063 alloy with SiC composites

Figure-2 shows variation of the percentage of elongation of Al 6063 alloy matrix and with 3, 6 & 9 wt. % of SiC particulate reinforced composites. From the figure-2, it can be observed that the % elongation of the composites is lesser than that of the matrix alloy. Further, from the graph, the trends of the % elongation can be found to be decreased with increase in SiC content in the composites. Increase in the reinforcement weight percentage decreases the ductile matrix content, thus minimizing the elongation. Manoj Kumar Gupta et al [11] produced Al /TiB_2 composite and investigated its mechanical properties. The aluminum alloy- titanium diboride composites were fabricated by the stir casting method with different particulate weight fractions (2%, 4%, 6%, and 8 %). It was found that the elongation of composites decreased with an increase in weight percentage of titanium diboride in the matrix material. The elongation of

composites is lower than that of un-reinforced Al-alloy. The mechanical properties of aluminum based composites reinforced with B_4C were investigated by J.Chandrasheker and N. V. S. Raju [13]. Stir casting was used to develop the Al7050/B_4C MMC samples with various B_4C weight fractions were produced (0, 3, 6, 9, and 12wt. percent). The results showed that the expansion of a weight level of B_4C reinforcement decreases the percentage of elongation in the composites.

4.3. Hardness

Figure-3 shows the graph between the hardness versus the SiC weight percent. From figure-3, it is observed that the hardness of composites is increased when the amount of reinforcement particulates increases. The presence of hard ceramic phase in the soft ductile matrix reduces the ductility of composites due to reduction of ductile metal content which significantly increases the hardness value. Dr. Manjunatha H.S et al [14] developed the TiB_2 reinforced AMCs and study the effect of reinforcements on the mechanical properties. In the present case, the TiB_2 content is varying in composition of (0, 3, 6, 9 and 12 wt %) in aluminum matrix, fabricated by stir casting technique. The authors observed that uniform distribution of the titanium diboride particles in the matrix phase, hardness of the composites increased with increasing the amount of the titanium diboride in the matrix phase. M. S. Sukumar et al [15] fabricated and analysed the mechanical properties of aluminium (Al6061 and Al7075) - aluminium oxide composites. Aluminium metal matrix composites are fabricated using stir casting process by varying the reinforcement percentage volumes between 0 and 10wt%, with 30µm particles size. The authors have revealed that the hardness of the MMCs is higher than the unreinforced matrix metal and the hardness of the cast composites increases linearly with increasing the weight fraction of Al_2O_3.

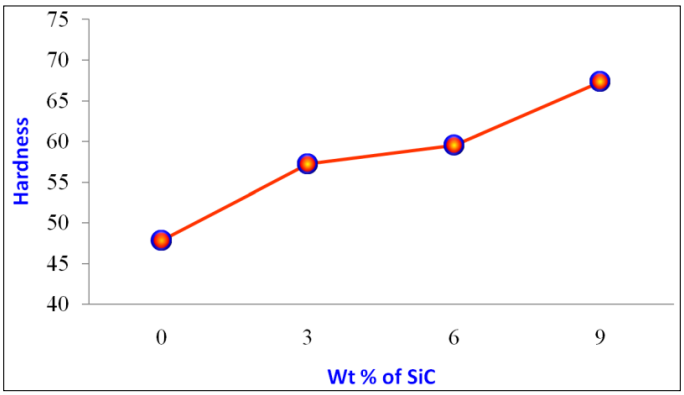

Figure 3 Hardness of Al 6063 alloy with SiC composites

5. Conclusion

The mechanical properties of Al 6063-SiC composites are prepared by the stir casting process with different SiC reinforcement proportions. The experimental results led to the following conclusions.

- Al 6063-SiC composites have shown higher tensile strength when compared to the tensile strength of Al6063 base alloy. Also tensile strength of composites increases with increasing wt. % of SiC reinforcement.
- The elongation of composites is lower than that of un-reinforced Al-alloy and the elongation of composites decreased with an increase in weight percentage of SiC in the matrix material.
- The hardness of the MMCs is higher than the unreinforced matrix metal and the hardness of the composites increases with increase in SiC percentage.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors have no conflicts of interest to disclose.

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