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Research Article

Mechanical properties of the as-cast silicon carbide particulate reinforced Aluminium alloy Metal Matrix Composites

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Abstract

In the present study, silicon carbide particulate reinforced LM6 alloy matrix composites were fabricated by green sand molding process by varying the particulate addition by weight fraction on percentage basis. Tensile properties and hardness tests studies were conducted to determine the tensile strength, modulus of elasticity and the hardness of the as cast MMCs. Microstructural properties of the as cast composites have also studied by using Scanning Electron Microscope. The experimental result reveals that the tensile properties and hardness of the as cast composites increases with the increasing the weight percentage of silicon carbide particulates in the matrix metal.

Key words*: LM6, SiCp, Metal matrix composites (MMCs), Hardness, Tensile Strength.*

1. Introduction

The need for engineering materials with the technological importance for the areas of air and land vehicles has led to a rapid development of composite materials. Composite materials have an edge over monolithic materials because of their superior properties such as high specific strength and stiffness, increased wear resistance, and enhanced temperature performance together with better thermal and mechanical fatigue and creep resistance (K.K.Chawla *et al*, 1998). Metal matrix composites (MMCs) are one of the important innovations in the development of advanced materials. Among the various matrix materials available aluminum and its alloys are widely used in the fabrication of MMCs and have reached the industrial production stage. The emphasis has given on developing affordable Al-based MMCs with various hard and soft reinforcements (SiC, Al2O3, zircon, graphite, and mica) because of the likely possibilities of these combinations in forming highly desirable composites (S. Ray *et al*, 1993).

Among discontinuous metal matrix composites, stir casting has generally accepted as a particularly promising route, currently practiced commercially. Its advantages lie in its simplicity, flexibility and applicability to large quantity production. It is also attractive because, in principle, it allows a conventional metal processing route to be used, and hence minimizes the final cost of the product. This liquid metallurgy technique is the most economical of all the available routes for metal matrix composite production (. M.K. Surappa *et al*, 1997), and allows very large sized components to be fabricated. The cost of preparing composites material using a casting method is about one-third to half that of competitive methods, and for high volume production, it is projected that the cost will fall to one-tenth (D.M. Skibo *et al*, 1998). In general, the solidification synthesis of metal matrix composites involves producing a melt of the selected matrix material followed by the introduction of a reinforcement material into the melt, obtaining a suitable dispersion.

Usually, the introduction of the SiC particles increases the elastic modulus and yield stress but decreases the ductility and toughness of the composites (R C Pavan *et al*, 2009). Optimizing the mechanical properties of the SiC reinforced aluminum alloy composites attracted continuous interest during the last several decades. The objective of the present investigation is to study the effect of varying weight percentage of SiCp on the mechanical properties of aluminum-silicon alloy (LM6) matrix composites solidifying in a five step sand mould.

2. Experimentation

The aluminum–silicon alloy i.e.LM6, which is a well known alloy of aluminum, is used as the base/matrix metal in the experiments for the fabrication of the composites that has been reinforced with 2.5 wt%, 5 wt%, 7.5 wt%, 10 wt% 12.5 wt % and 15 wt. % of SiCp of average 400 mesh size. The chemical composition of the matrix material (LM6) and the thermo physical properties of SiCp & LM6 are given in the table-1 & table-2. The composites are fabricated by the liquid metal stir casting technique. The melting is carried in a tilting electric resistance furnace in

R.Behera is working as Asst. Professor, G.Sutradhar is Professor and Sourav Kayal is S.R.F under DST-PURSE Scheme in the department of mechnanical engineering,.

a range of 760 ± 100C. Photograph of the furnace is shown in Figure 1.

Fig.1 Electric resistance furnace with Stirring System for melting of matrix metal i.e. LM6 and mixing of SiCp with the Liquid LM6.

The melt mechanically stirred by using an impeller after addition of the pre-heated silicon carbide particle (about 1000^0C.). The processing of the composite is carried out at a temperature of 750^0C with a stirring speed of 600 rpm. The melt is poured at a temperature of 730 ^{0}C into a stepped silica sand mould. Finally, the micro structural characteristics and mechanical properties of the composites are evaluated.

Table 1 Chemical Composition (LM6)

Element	Percentage
Si	10 to 13
Cu	0.1
Mg	0.1
Fe	0.6
Mn	0.5
Ni	0.1
Zn	0.1
Pb	0.1
Sb	0.05
Ti	0.2
Al	Balance

Table 2 Thermo physical properties of reinforcement particle and LM6

Properties	SiC particulates	LM6
Density(gm/cm^3)	3.2	2.66
Average particle size(mesh)	400	-----
Thermal conductivity(W/m/K)	100	155
Specific heat (j/Kg/K)	1300	960

3. Results and discussion

3.1. Tensile Strength

Tensile tests are carried out by using an UTM to determine the tensile properties of the material such as ultimate tensile strength and Young's modulus (Richardson *et al*, 1987). Round tensile specimen with the gauge diameter 6.35 ± 0.1 mm and gauge length of 25.4 mm as per ASTM standard B557 M-94 specification as shown in Figure 2 are used for tensile testing. The photograph of the tensile test specimens after testing has shown in Figures 3.

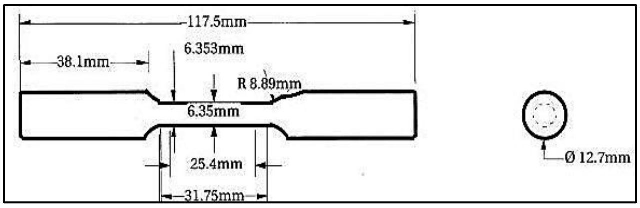


Fig. 2 Dimension of standard tensile sample

For every weight fraction addition of SiC particulate, four specimens are tested and all the steps are repeated for consecutive specimens which contain different weight fraction of SiC particulates in LM6 alloy matrix.

Fig. 3 Test specimen after test

Figure 4 and 5 plotted between the average tensile strength and modulus of elasticity values versus variation in weight fraction of SiC particulate addition to LM6 alloy shown below indicates that both the properties increase on increasing the weight fraction of SiC particles in the matrix metal.

Dispersion of hard ceramic particles in a soft ductile matrix results in improvement in strength (H.B. Niranjan *et al*,1998). This may be attributed to large residual stress developed during solidification and due to mismatch of thermal expansion between ceramic particles and soft aluminium matrix as corroborated also in (W.J. Clegg *et al*, 1998). The increase in strength may also be result of closer packing of reinforcement with soft aluminium matrix. Wettability is one of the dominating factors to ensure good bonding between the matrix and reinforcement (B.C. Pai *et al*, 1995). A good bonding between reinforcement and soft aluminium matrix favors an enhancement of the ultimate tensile strength of the composite (v *et al*, 2003).

Table 3 Average tensile strength and Young's modulus value with variation in the weight fraction of SiC particulate

Weight fraction % Of SiC	Tensile strength (MPa)	Modulus of elasticity (MPa)
0	175.234	14663.404
2.5	208.465	19659.788
5	215.348	20240.181
7.5	221.479	20812.458
10	230.468	21651.784
12.5	235.648	22157.908
15	243.786	22938.487

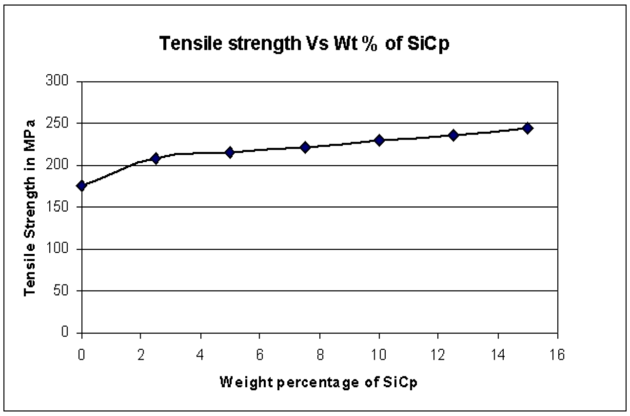


Fig. 4 Average tensile strength Vs weight fraction of SiC

3.2. Hardness

Hardness test is conducted on each specimen using a load of 250 N and a steel ball of diameter 5 mm as indenter. Diameter of impression made by indenter is predicted by Brinnel microscope.

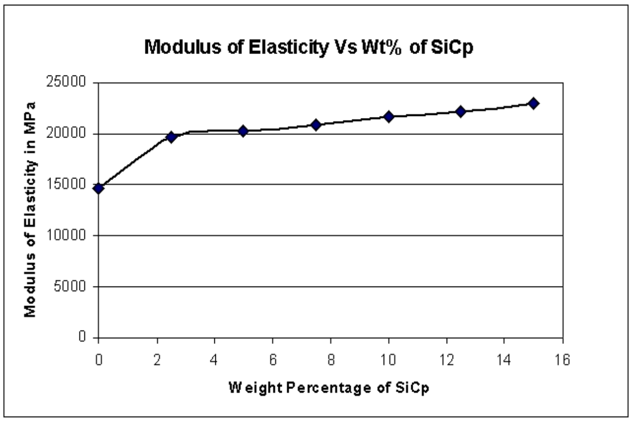


Fig 5 .Modulus of elasticity Vs weight fraction of SiC

The corresponding values of hardness (BHN) calculated from the standard formula. Hardness values of the test samples of the silicon carbide particulate reinforced LM6 alloy matrix composites having different weight fractions are tabulated in Table 4.

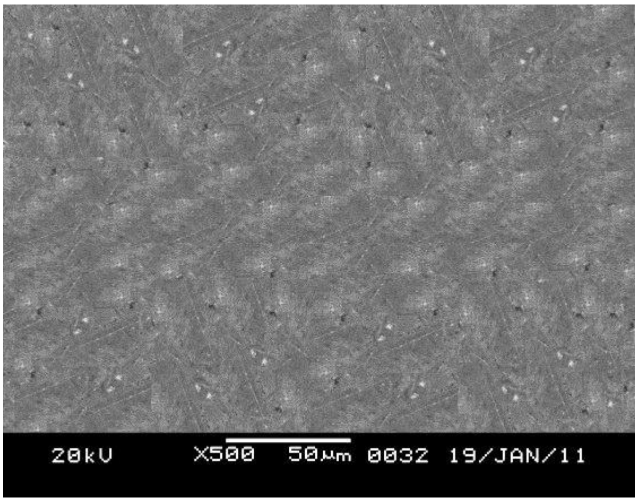
Table 4 LM6 alloy matrix composites having different weight fractions

Material	Hardness(BHN)
LM6	53.5
LM6-2.5% Wt	63.8
LM6-5%Wt	64.6
LM6-7.5%Wt	65.1
LM6-10%Wt	66.7
LM6-12.5%Wt	67.4
LM6-15%Wt	68.2

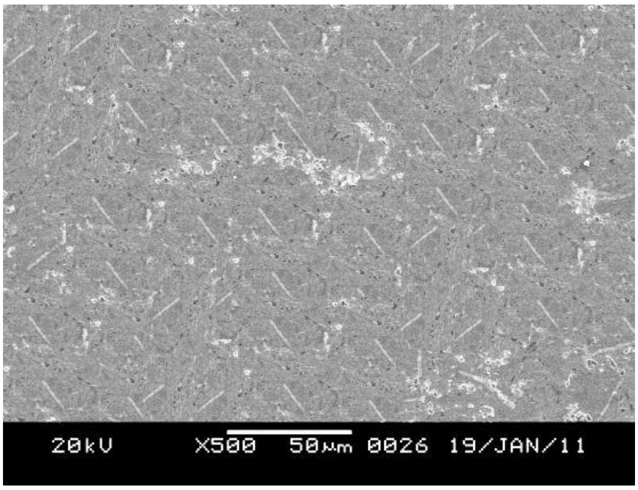
Based on the above hardness data, the variation in hardness value of the composites corresponding to the variation in weight fraction of silicon carbide particulate can be known. It is clear in this table that the hardness value of the processed composites increases with the increase in addition of silicon carbide particulate by weight fraction %.

3.3. Microstructural Analysis

Samples of as cast MMCs for metallographic examination are prepared by grinding through different size of grit papers followed by polishing with 6μm diamond paste. Then the samples are etched with the etchant i.e. Keller's reagent (2.5 ml Nitric acid, 1.5 ml HCl , 1.0 ml HF,95.0 ml Water) . The etched samples are dried by using electric drier and then the microstructure observed by using Scanning Electron microscope (JEOL, JSM 6360). The microstructure of the as cast LM6/SiCp MMCs are shown in Figure 6 (a-f) at different weight fraction of SiCp.



(a)



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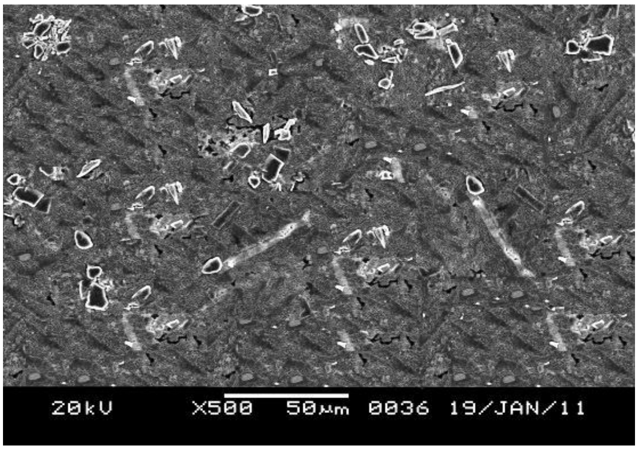
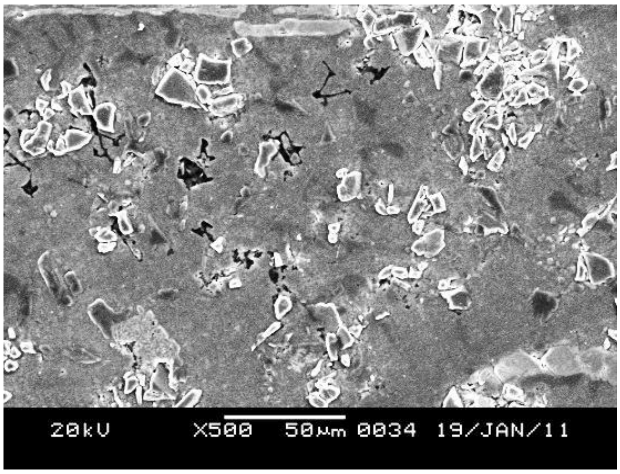
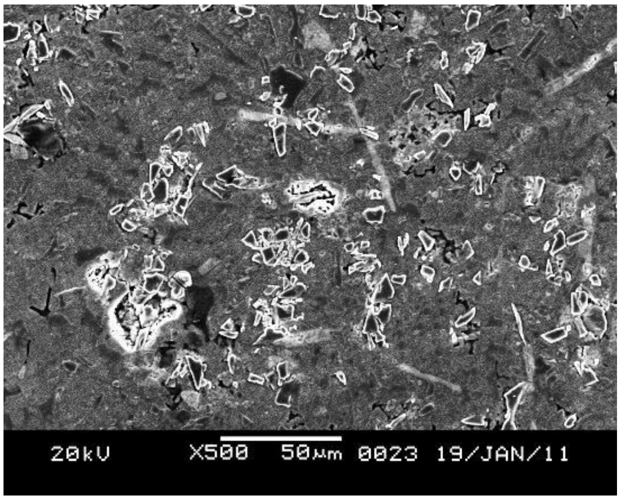


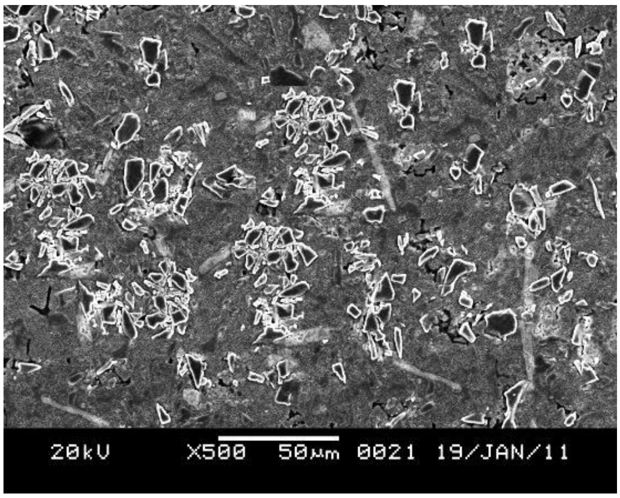
(c)



(d)

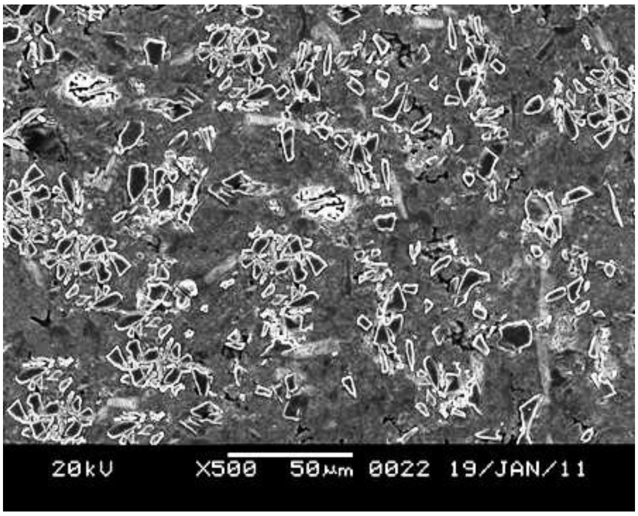


(e)



(f)

Fig. 6 predicts that the main micro structural features in cast composites have been in the form of dendrites. The SiC dispersiods in the crystal structure of aluminum were in solid solution, and have been distributed among the



(G)

Fig.6. Microstructure of LM6/ SiCp as cast MMCs at different Weight fraction of SiCp. (a)LM6,(b) 2.5%wt% of SiCp.(c) 5%wt% of SiCp (d)7. 5%wt% of SiCp (e) 10%wt% of SiCp (f) 12. 5%wt% of SiCp (g) 15%wt% of SiCp

aluminum atoms in an atomic dispersion. The composites does not freeze at a single temperature but instead over a temperature range (temperature at which the freezing begins was called the liquidius, and the temperature at which freezing was complete is called the solidus (Richard A *et al*).
The phenomenon of dendrite structure formation may be due to supercooling effect in which certain preferred regions protrude as spikes into the supercooled regions and once started, grow more rapidly then neighboring regions. This had happened because the driving force for freezing was greater in the super cooled regions and the spikes reject the solute at their sides, thus delaying freezing of the side regions. These spikes consequently tend to form side arms producing a dendritic structure.

Nucleation of α- Al phase starts in the liquid at a distance away from the particles, where the temperature was lower. The growth of α- Al nuclei lead to enrichment of Si in the melt. The enrichment of Si in the melt around the particles leads to heterogeneous nucleation. Another effect of thermal lag was that the melt around the particles would solidify in the last stage. This would make the particles located between dendrites. In other words, the interdendritic clusters of SiC particles have been partly inherited from inhomogeneous distribution of particles in the original slurries. In commercially pure aluminium (without SiC particles), dendrites were observed to be distinctively columnar and almost randomly distributed
However, in cast composites, dendrites were found to be equiaxed and in the regions with clusters of SiC particles in the primary α- Al seemed to be finer.

4. Conclusions

In this experimental study, quantification of strength and hardness of silicon carbide particulate reinforced LM6 alloy matrix composites test specimens after tensile testing has described. Based on the experimental evidence from this research work the following conclusions have made and it has listed below:
1) The results of study suggest that with increase in weight fraction of SiCp, an increase in hardness has observed.
2)The split tensile strength and Young's modulus values increased gradually as the silicon carbide content in the composite increased from 2.5% to 15% by weight fraction
3) The microstructural results reveal that the silicon carbide particles have uniformly distributed throughout the MMC castings.

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