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Effect of reinforcement of AL-6063 with SiC on mechanical behavior and microstructure of metal matrix composites

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Abstract: A phrase heard often in recent years, advanced composite materials like Al/SiC metal matrix composite is gradually becoming very important materials in auto and aerospace industries due to their superior properties. The present study examines the mechanical properties of aluminum (Al-6063)/SiC Silicon carbide reinforced particles metal-matrix composites (MMCs) by varying weight fractions of SiC. For this (Al-6063)/SiC reinforced particles MMCs are fabricated by stir casting method at air atmosphere . The MMCs are prepared in the form of bars with varying the reinforced particles by weight fraction ranging from 2 %, 4 %, 6 %, 8 % and 10 %. The reinforced particles size of SiC is varying between 25-40 microns. The microstructure study shows that the distribution of particles becomes better with increasing weight fraction of SiC. The Mechanical properties like, Ultimate tensile strength (MPa), % Elongation, Hardness (HRB), Yield Strength (N.m) are investigated on prepared specimens of MMCs. It was observed that the hardness of the composite is increased gradually from 2-6 % and drastically from 8-10%. The tensile strength and ultimate break load are increased with rising of reinforced weight fraction and the improvement varies between 15.8- 27 % and 2-15 % respectively.

Key words: Aluminium, SiC, Metal Matrix Composite, stir casting, weight fraction

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1. Introduction : Metal Matrix Composite (MMC) is one of the major renovations in recent years and is engineered combination of metal (Matrix) and hard particles (Reinforcement) to mechanical properties. the mechanical properties of MMCs increases their usage in automobile industries [1] Metal Matrix Composites (MMC's) have very light weight, high strength, and exhibit greater resistance to corrosion, oxidation and wear [2]. The improvement of tribological properties of materials has been studied to raise the load bearing capacity of materials [3-4]. The effect of wire electrical discharge machining) parameters of the Al6063 reinforced with SiC in the form of particles with 5%, 10% and 15% volume fractions has been studied [5]. Fatigue resistance is an especially important property of Al-MMC, which is essential for automotive application. These properties are not achievable with lightweight monolithic titanium, magnesium, and aluminium alloys.

Particulate metal matrix composites have nearly isotropic properties when compared to long fibre reinforced composite. Only the mechanical behaviour of the composite depends on the matrix material composition, size, and weight fraction of the reinforcement and method employed to construct the composite. The dispersion of the reinforcement particles in the matrix alloy is influenced by various genes such as behaviour of the matrix melt, the particle incorporation method, interaction of particles and the matrix before, during, and after mixing [6 - 7].

Non homogeneous particle distribution is one of the greatest problems in casting of metal matrix composites. The distribution of the reinforcement material in the matrix must be uniform and the wetability or bonding between these substances should be optimized. Aluminum-silicon carbide metal matrix composite has low density and light weight, high temperature strength, hardness and stiffness, high fatigue strength and wear resistance etc. in comparison to the monolithic materials **[8-10]**. This paper presents the study of microstructure and mechanical behaviour when aluminium is reinforced with different weight fraction of SiC.

II. MATERIALS AND METHODS

A. Aluminum with silicon carbide : The reinforced metal matrix composite material selected for present investigation was based on AL6063 matrix alloy source of materials in Table.1.and its chemical composition is shown in Table (2). The matrix material used in the present investigation was pure aluminium The different volume fraction of silicon carbide particulate aluminum alloy (6063) composite was used for this investigation. The equipment used includes a crucible furnace, stainless steel stirrer (powered by a motor), a thermocouple, heat treatment furnace, tensile, impact and hardness testing machines and an optical microscope is used for micro structural evaluation [11-15]

Table (1): Source of Materials

No	Materials	Supplied by
1	Aluminum 6063	General Foundries Ltd. Bangalore.
2	Silicon carbide	Hindustan Traders Chennai.

Table (2): Chemical composition of Al Alloy (AL6063)

Element	Composition	Element	Composition
Si	0.4430	Zn	0.0001
Fe	0.1638	Cr	0.0024
Cu	0.0041	Ti	0.0078
Mg	0.5382	Ca	0.0003
Mn	0.0132	Al	98.751

Final metal matrix composite material undergoes the fabrication and testing methods as stated below:

a) Stir casting method
b) Hardness test
c) Tensile test

B. Manufacturing process

a) Stir casting method: First of all stirring system has been developed by coupling motor with gearbox and a mild steel stirrer as shown in Figure (1). All the melting was carried out in a graphite crucible in an oil-fired furnace. Scraps of aluminum were preheated at 450 ^{0}C for 3 to 4 hours before melting and mixing the SiC powdered particles were preheated at 1100^{0}C for 1 to 3 hours to make their surfaces oxidized. The furnace temperature was first raised above the liquids to melt the alloy scraps completely and was then cooled down just below the liquids to keep the slurry in a semi-solid state. At this stage the preheated SiC powdered particles were added and mixed manually. Manual mixing was used because it was very difficult to mix using automatic device when the alloy was in a semi-solid state. After sufficient manual mixing was done, the composite slurry was reheated to a fully liquid state and then automatic mechanical mixing was carried out for about 10 minutes at a normal stirring rate of 600 rpm. In the final mixing process, the furnace temperature was controlled within 760 ± 100C. Pouring of the composite slurry has been carried out in the sand mold prepared.

Figure (1): Stir casting unit

b) Hardness Test : The Brinell hardness test for the cast samples was conducted on a 15 mm x 10 mm test pieces. Both grinding and polishing were carried out starting with coarse filing and finishing using a motor-driven emery belt. A load of 125 kg was applied on the test piece for 15 seconds and the diameter of the impression measured. The average hardness values of the test pieces are displayed in Table (2).

c) Tensile Test : As per ASTM B557M standard, tensile strength was determined by instron computerized tensile compression testing. The specimen used for testing was machined according to ASTM B557 standards. the specimens before and after the test are shown in Figure (3 and 4) respectively. The graph between strength and strain was obtained by using auto instrument software is shown. The ultimate breaking load, elongation and ultimate stress were observed to be increasing wt.% of SiC.

The cup and cone fracture obtained in the work piece by tensile test it can be seen that the tensile strength increases with increasing wt.% of SiC. It can be observed that the tensile strength of the composites is higher than that of the matrix alloy. Further, from the graph, the trends of the tensile strength can be found to be increased with increase in SiC content in the composites. This improvement in tensile strength of the composites may be attributed to the fact that the filler SiC possesses higher strength and also may be due to the better bonding strength due lower fineness of dispersed particulates

Figure (2): Tensile testing equipment

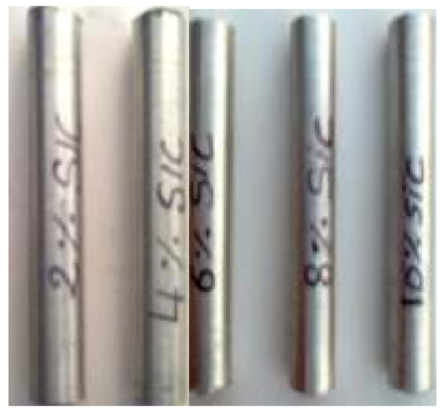

Figure (3): Test specimens

Figure (4): Tested specimens

III. RESULTS AND DISCUSSIONS

The effect of reinforcement of aluminium with different weight fraction of SiC on microstructure and mechanical behavior is studied. It is noted that the increase in reinforcement increases the Hardness, Tensile Strength, Yield Strength, and Ultimate Break Load. It is experimentally observed that the elongation of composites is gradually decreased than that of unreinforced aluminium.

Figure (5) shows that the hardness increases when wt.% of silicon carbide with aluminium 6063 increases. It was observed that the hardness of the composite is increased gradually from 2 to 6 wt.% and drastically from 8 to 10 wt.%. The Hardness values of Al6063+SiC is presented for various weight fractions of SiC in Table (3). Figure (6 & 7) also shows that the increase in wt.% of SiC with aluminium increases the tensile strength, ultimate break load. The improvement of tensile strength, ultimate break varies between 15.8 - 27 % and 2 - 15 % respectively. This is imputable to the uniformity of dispersion of particles in the reinforcement is better when SiC weight fraction is increased during pouring and solidification.

Figure (8) shows that the variations of Yield strength is gradually improved to increase in weight fraction of SiC. It can also seen from the Figure (9) the percentage elongation decreases gradually with risings of SiC weight fraction with aluminium.It lets out that the rising of weight fraction of SiC in aluminium will give better results in improvement of yield strength and it varies between 22 - 35 %. This is due to the improvement in uniformity of particle distribution while pouring and preventing agglomeration during solidification

Table (3): Hardness values of Al6063+SiC

Sample I.D	2%	4%	6%	8%	10%
1	25.3	29.5	32.6	88.2	83.8
2	23.9	30.2	33.3	87.0	87.8
3	25.8	29.8	32.2	85.1	87.1

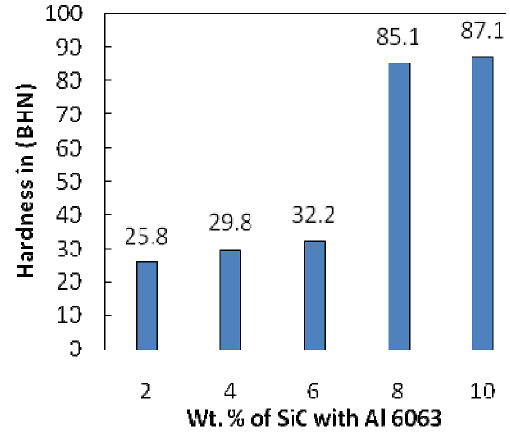

Figure (5): Hardness of Al 6063+SiC.

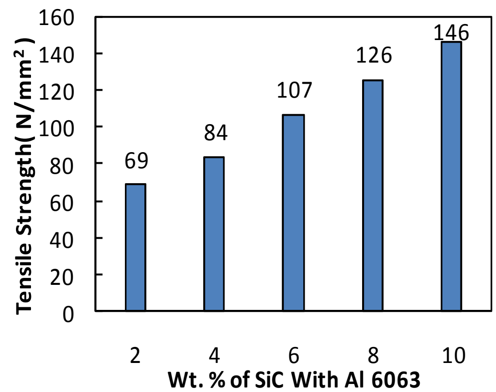

Figure (6): Tensile Strength of Al 6063+ SiC.

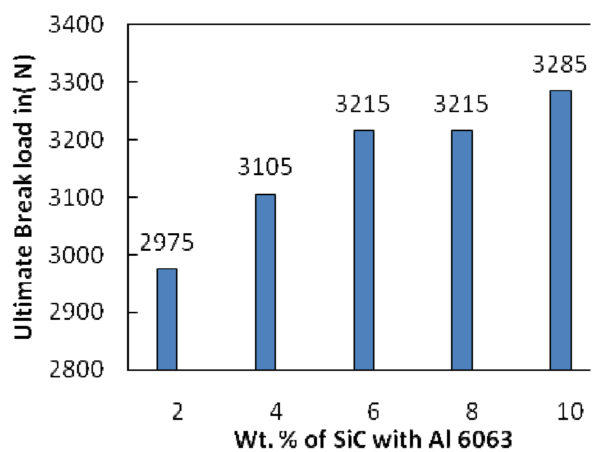

Figure (7): Ultimate Break load of Al 6063+ SiC.

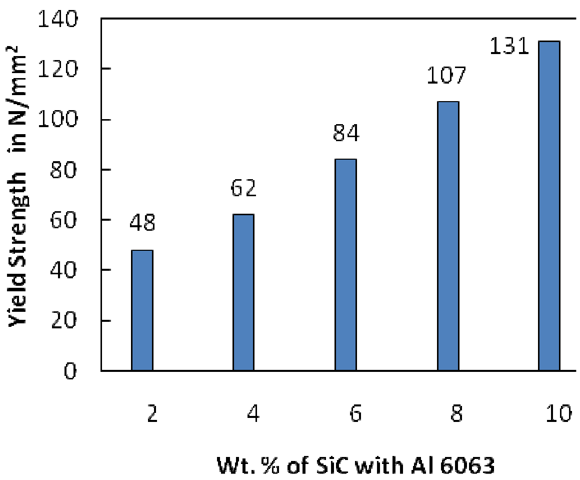

Figure (8): Yield Strength of Al 6063+ SiC

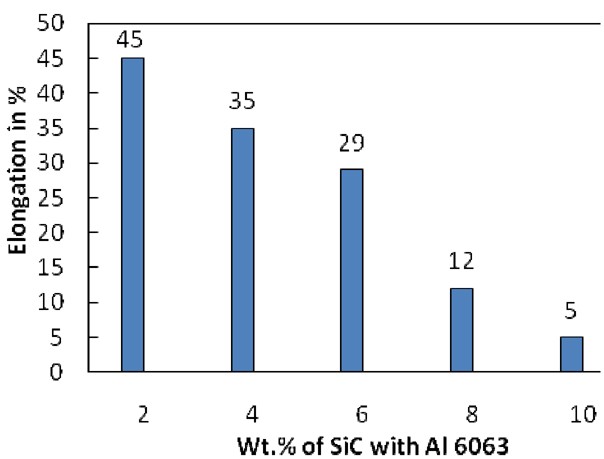

Figure (9): Elongation in Percentage of Al 6063+ SiC.

IV. Optical Micrographs of Al 6063+ SiC MMCs:

The properties of particulate composites are mainly influenced by the morphology, type of reinforcing Particles and its distribution. The type of reinforcement and the method of incorporation are very important variables that affect the distribution of particles. It is necessary to distribute particles uniformly throughout the casting during production of particulate composites. The primary purpose of this MMC's is to get a homogeneous dispersion of molecules in the liquid melt and then to prevent agglomeration of particles during pouring and the progress of solidification.

The microstructures of the samples, prepared from the casting part at different locations, were noted at aluminium 6063 with reinforcement of 2, 4, 6, 8, 10 wt.% of silicon carbide particles to study the particle distribution. The optical micrographs of metal matrix composites are shown in Figure (10 – 14). Well-formed nodules were observed grain boundaries were observed after etching process. It can be seen from the Figure (10 and 11), it is identified from the samples 2 and 4 wt. % of SiC resembles less the degree of particles distribution when compare with 6 wt.%. Because Figure (12) shows that the particles distribution is moderately better. Figure (13) and Figure (14) shows that the distribution is more uniform than the other cases due to less segregation during solidification. It clearly shows that the increase of uniformity in particle distribution leads better mechanical behaviour.

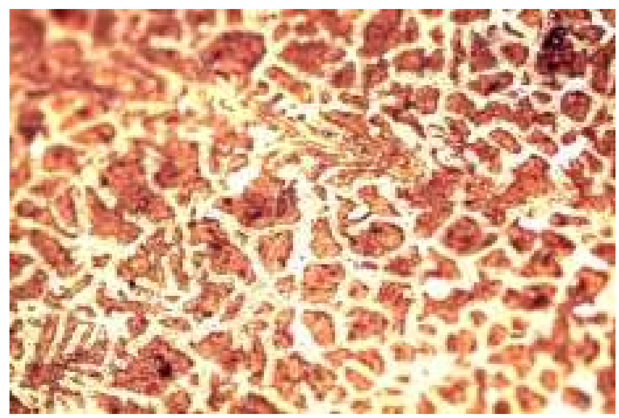

Figure (10): Optical micrograph (100X) of Al6063/ (2 wt.% SiC)

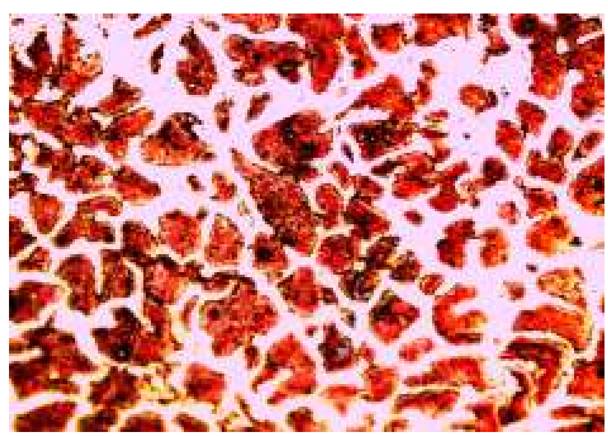

Figure (11): Optical micrograph (100X) of Al6063/ (4 wt. % SiC).

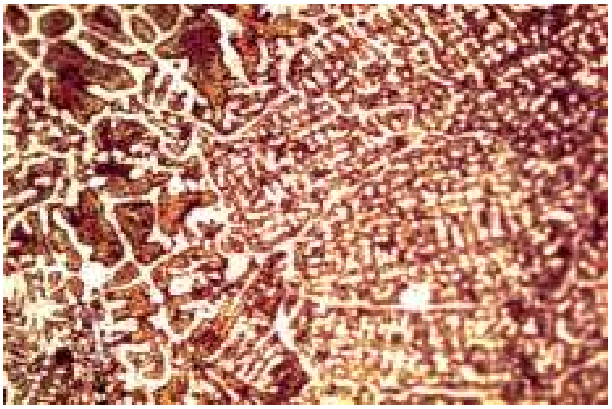

Figure (12): Optical micrograph (100X) of Al6063/ (6 wt % SiC).

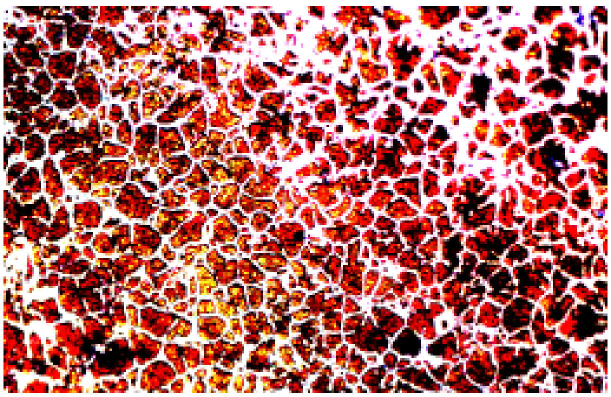

Figure (13): Optical micrograph (100X) of Al6063/ (8 wt.% SiC).

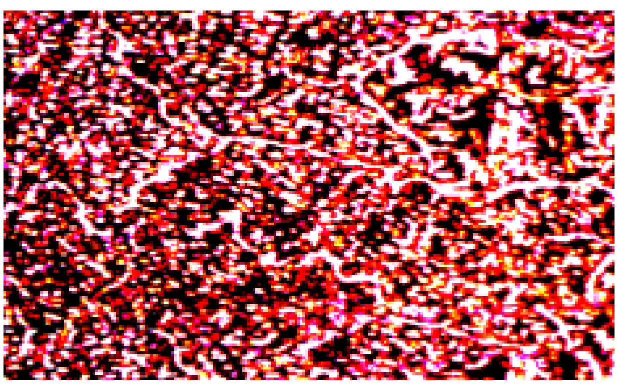

Figure (14) : Optical micrograph (100X) of Al6063/ (10 wt. % SiC).

V. Conclusions

The microstructure and mechanical behavior by reinforcement of aluminium with different weight fraction of SiC has been examined. The specimens were prepared by stir casting method with weight fractions of SiC as per the standard of as per ASTM B557M to find the mechanical behavior. Brinell hardness test was carried out to find out hardness and optical microscope was used to obtain the microstructure at different locations of specimens. From the test results It was observed that the hardness of the composite is increased gradually from 2 % to 6 % and drastically from 8 % to 10 %. Further the increase in wt.% of SiC with aluminium increases the tensile strength, ultimate break load. The improvement of tensile strength, ultimate break load varies between 15.8 - 27 % and 2 - 15 % respectively. Yield strength is gradually improved to increase in weight fraction and It lets out that the rising of wt. % of SiC in aluminium will give better results in improvement of yield strength and it varies between 22 - 35 %. From the microstructure results the samples 2 wt. % and 4 wt. % of SiC resembles less the degree of particles distribution when compare with 6 wt. % the dispersion of particles is moderate in 6 wt. % samples. But 8 & 10 wt. % samples gives distribution is more uniform than the other cases because of less segregation during solidification. It clearly shows that the increase of uniformity in particle distribution leads better mechanical behaviour. So there is no doubt in that the application of this material in auto and space industries will be scope for the future.

VI References:

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