



## Experimental Investigation to Analysis of Mechanical Properties of the Developed Al/SiC-MMC's

Bahul Saroya<sup>1</sup>, Prof Doordarshi Singh<sup>2</sup>, Dr. Jaswanti<sup>3</sup>, K.L.Meena<sup>4</sup>

<sup>1,2</sup>Department of Mechanical Engineering, Baba Banda Singh Bhadur College of Engg. & Tech, Fatehgarh, India

<sup>3</sup>Department of Electrical Engineering, Chandigarh College of Engg & Tech, Chandigarh, India

<sup>4</sup>Department of Mechanical Engineering, Chandigarh College of Engg & Tech, Chandigarh, India

### ABSTRACT

Metal Matrix Composites (MMC's) have evoked a keen interest in recent times for potential applications. Advance composite materials like Al/SiC metal matrix composite is gradually becoming very important materials in manufacturing industries e.g. aerospace, automotive and automobile industries due to their superior properties such as light weight, low density, high strength to weight ratio, high hardness, high temperature and thermal shock resistance, superior wear and corrosive resistance, high specific modulus, high fatigue strength etc. In this study aluminum (Al-6063)/SiC Silicon carbide reinforced particles metal-matrix composites (MMCs) are fabricated by melt-stirring technique. The MMCs bars and circular plates are prepared with varying the reinforced particles by weight fraction ranging from 5%, 10%, 15% and 20%. The average reinforced particles size of SiC are 220 mesh, 300 mesh, 400 mesh respectively. The stirring process was carried out at 200 rev/min rotating speed by graphite impeller for 15 min. The microstructure and mechanical properties like Proportionality (MPa) limit, Tensile strength upper yield point (MPa), Tensile strength lower yield point (MPa), Ultimate tensile strength (MPa), Breaking strength(MPa), % Elongation, % Reduction in area, Hardness (HRB) ,Density (gm/cc), Impact Strength (N.m) are investigated on prepared specimens of MMCs. It was observed that the hardness of the composite is increased with increasing of reinforced particle weight fraction. The tensile strength and impact strength both are increased with rising of reinforced weight fraction. Different mechanical tests were conducted and presented by varying the particle size and weight fractions of SiC.

**Key words :** Metal Matrix Composites (MMC's), Silicon Carbide (SiC), Melt stirring technique.

### 1. INTRODUCTION

Metal Matrix Composite ( MMC) is engineered combination of metal (Matrix) and hard particles (Reinforcement) to tailored properties. Metal Matrix Composites (MMC's) have very light weight, high strength, and stiffness and exhibit greater resistance to corrosion, oxidation and wear. 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. But the mechanical behavior of the composite depends on the matrix material composition, size, and weight fraction of the reinforcement and method utilized to manufacture the composite. The distribution of the reinforcement particles in the matrix alloy is influenced by several factors such as rheological behavior of the matrix melt, the particle incorporation method, interaction of particles and the matrix before, during, and after mixing [1]. Nonhomogeneous particle distribution is one of the greatest problems in casting of metal matrix composites [2]. Nai and Gupta [3] reported that the average coefficient of thermal expansion of the high SiCp end was reduced as compared to that of the low SiCp end. Hashim et al. [4] reported that the distribution of the reinforcement material in the matrix must be uniform and the wettability 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 [5]. However, aluminum alloy with discontinuous ceramic reinforced MMC is rapidly replacing conventional materials in various automotive, aerospace, and automobile industries [6]. Amongst various processing routes stir casting is one of the promising liquid metallurgy technique utilized to fabricate the composites. The process is simple, flexible, and applicable for large quantity production. The liquid metallurgy technique is the most economical of all the available technique in producing of MMC [7]. Aluminum alloy-based composites containing 10wt% alumina (size range: 150\_225 mm) were prepared by liquid metallurgy technique using the vortex method [8,9]. The ZnO whiskers 25 vol% reinforced with Al-matrix composites were fabricated by a squeeze casting process [10]. The quartz-silicon dioxide particulates reinforced LM6 alloy matrix composites were fabricated by carbon dioxide sand molding process [11]. Various researchers have utilized conventional stir casting technique for producing MMC [12]

Elements of Al 6063	Si	Mn	Mg	Cu	Fe	Ti	Al
%	0.44	0.07	0.6	0.018	0.2	0.008	98.664

but still applied research is needed for successful utilization of the process for manufacturing of MMC.

In this study stir casting is accepted as a particularly promising route, currently can be 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 [13], 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 [14]. 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. The next step is the solidification of the melt containing suspended dispersoids under selected conditions to obtain the desired distribution of the dispersed phase in the cast matrix. In preparing metal matrix composites by the stir casting method.

From the past review, it is found that the number of research work on wear behaviour of MMCs have been published, but only few work related to the influence of weight fraction on mechanical properties like tensile strength, hardness, impact strength, percentage of elongation etc. have been reported. In this study, different weight fractions of Silicon Carbide particulates are added with aluminium matrix to fabricate the Al/SiC metal matrix composites. Different samples have been fabricated by melt-stirring casting and their microstructure, hardness, tensile strength, and impact strength are studied. In this study the influences of the reinforced particulate size (220 mesh, 300 mesh, 400 mesh) and weight fraction (5%,10%,15%,20%) on mechanical properties like Proportionality (MPa) limit, Tensile strength upper yield point (MPa), Tensile strength lower yield point (MPa), Ultimate tensile strength (MPa), Breaking strength(MPa), % Elongation, % Reduction in area, Hardness (HRB) ,Density (gm/cc), Impact Strength (N.m) are investigated.

## 2. FABRICATION OF AL/SiC METAL MATRIX COMPOSITES

Silicon Carbide (SiC) reinforced particles of average particle size 220 mesh, 300 mesh, 400 mesh respectively are used for casting of Al-MMC,s by melt-stir technique. Table 1 represents the chemical composition of commercially available Al-matrix used for manufacturing of MMC. Different dimensions of round bars with 5 vol%, 10 vol%,15

vol% and 20% of reinforced particles of size 220 mesh, 300 mesh, 400 mesh respectively .

Table 1. Chemical composition of matrix Al 6063 alloy. Experiments were carried out to study the effect of settling the reinforced particulates on the solidification microstructure and mechanical properties of the cast MMC. In the present study, commercially available aluminium (AA6063) is used as matrix reinforced with Silicon Carbide (SiC) particulates. The melting was carried out in a clay-graphite crucible placed inside the resistance furnace. An induction resistance furnace with temperature regulator cum indicator is utilized for melting of Al/SiC-MMCs. Figure 1(a) shows an induction resistance furnace and temperature regulator cum indicator, respectively. A design and developed stirring setup is shown in Figure 1(b). Aluminium alloy (Al 6063) was first preheated at 450<sup>o</sup>C for 2 h before melting and SiC particulates were preheated at 1100<sup>o</sup>C for 1 h 30 min to improve the wetting properties by removing the absorbed hydroxide and other gases. The furnace temperature was first raised above the liquidus temperature, that is, 750<sup>o</sup>C, to melt the matrix completely and then it was cooled down to just below the liquidus temperature to keep the slurry in a semi-solid state. At this stage the preheated SiC particles were added and mixed mechanically. The composite slurry was then reheated to a fully liquid state and mechanical mixing was carried out for 20 min at 200 rpm average stirring speed. In the final stage of mixing, the furnace temperature was controlled within 760 ± 10<sup>o</sup>C and the temperature was controlled at 740<sup>o</sup>C. Moulds (size 40mm diameter ×170 mm long) made of IS-1079/3.15mm thick steel sheet were preheated to 350<sup>o</sup>C for 2 h before pouring the molten Al/SiC -MMC. Figure 2(a) shows mixing again manually before pouring. Figure (b) shows pouring mixture of molten Al and SiC particles. Then fabrication of composite was followed by gravity casting. Similar process was adapted for preparing the specimens of varying mesh size and weight fractions.



Fig. 1. (a), (b) Induction resistance furnaces with temperature regulator cum indicator.



Fig. 2. (a) Mixing again manually before Pouring (b) Pouring mixture of molten Al and SiC particles.

### 3. RESULTS AND DISCUSSION

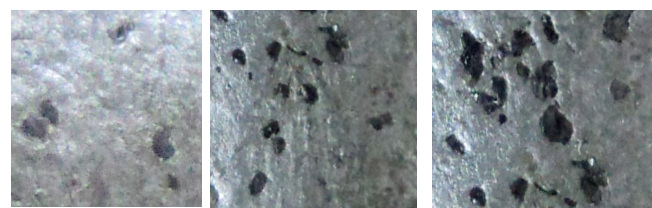
Various Experiments were conducted on fabricated MMCs samples by varying weight fraction of SiC (5%, 10%, 15%, 20 %,.) and size of SiC particles (220 mesh, 300 mesh, 400 mesh) to analyze the casting performance characteristics of Al/SiC-MMCs.

#### 3.1 Microstructure

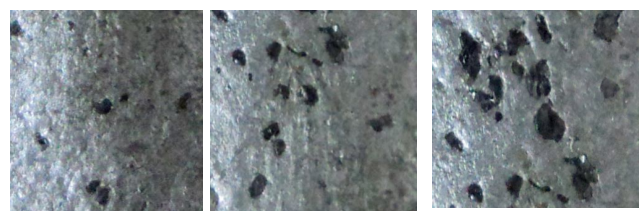
Metallographic samples were sectioned from the cylindrical cast bars. A 0.5 % HF solution was used to etch the samples wherever required. To see the difference in distribution of SiC particles in the aluminium matrix, microstructure of samples were developed on Inverted type Metallurgical Microscope (Make: Nikon, Range-X50 to X1500). Figure 3 shows Micrograph of Al/SiC-MMC's samples for different Sizes (220 mesh, 300 mesh, 400 mesh) and weight fraction (5%, 10%, 15%, 20 %,.) of SiC particles. Optical micrographs showed reasonably uniform distribution of SiC particles. In this Al matrix SiC particles are clearly labelled.



Al /Wt.5% SiC , Al /Wt.10% SiC , Al /Wt.20% SiC , 200 mesh



Al /Wt.5% SiC , Al /Wt.10% SiC , Al /Wt.20% SiC , 300 mesh



Al /Wt.5% SiC , Al /Wt.10% SiC , Al /Wt.20% SiC , 400 mesh

Fig. 3. Micrograph of Al/SiC-MMC's samples for different Sizes and weight fraction of SiC particles.

#### 3.2 Tensile Strength

The tensile test was carried out at room temperature on Universal Testing Machine Model-UTN-20, Sr.No.-4/79/239, Max. Capacity-2000 kgs, Make Blue Star Ltd. Fig. 4. shows standard dimensions of specimen for Tensile Test. Test specimens of standard dimensions as shown in fig.5. were prepared of Al/SiC-MMC's for different size (220 mesh, 300 mesh, 400 mesh) and weight fraction (5%,10%,15%,20%) of SiC particles.

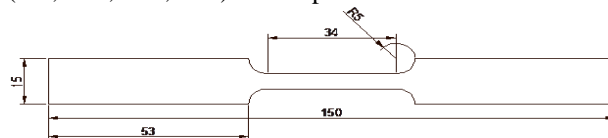


Fig. 4. Standard specimen for Tensile Test



Fig. 5. Standard specimen prepared by varying the mesh size and Wt. fraction of SiC for Tensile Test



Fig. 6. (a) UTM Machine (b) Testing of specimen on UTM Machine (c) Specimens after test

Procedure of Tensile Test is shown by fig. 6. (a) and (b) In fig.6 (c) Twelve Specimens are shown after test. Graphs were plotted between tensile force (kgf) and Extension (mm) for twelve specimens. The values of tensile force are plotted on vertical axes and extension on horizontal axes. The specimen passes through the clearly defined stages i.e limit of proportionality, Upper yield value, lower yield value, ultimate stress value and finally fractures strength value.

Effect of size and weight fraction of SiC particles of Al/SiC-MMC's on mechanical properties like Proportionality (MPa) limit, Tensile strength upper yield point (MPa), Tensile strength lower yield point (MPa), Ultimate tensile strength (MPa), Breaking strength(MPa), % Elongation, % Reduction in area, Hardness (HRB) , Density (gm/cc), Impact

Strength (N.m) are presented in graphs [fig.11 to 14] as shown hereunder. In these graphs all above properties are taken on vertical axes and Wt.% of SiC on horizontal axes.

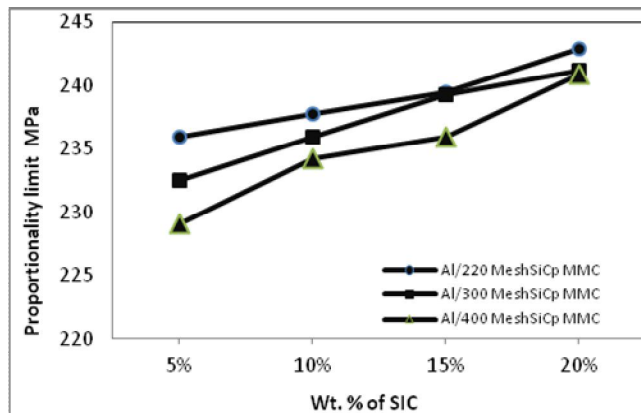


Fig. 11. Proportionality (MPa) limit Vs Wt.% of SiC

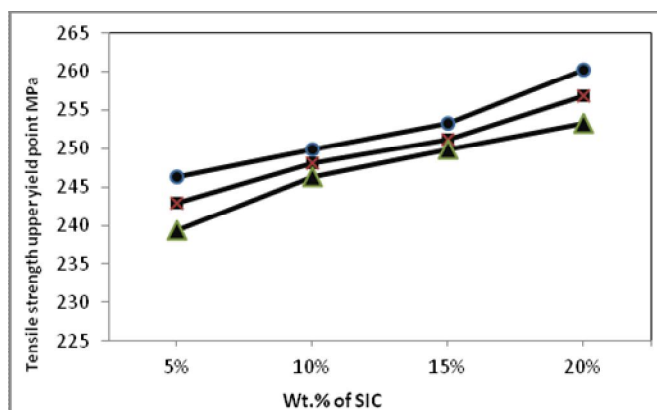


Fig. 12. Tensile strength upper yield point (MPa) Vs Wt.% of SiC

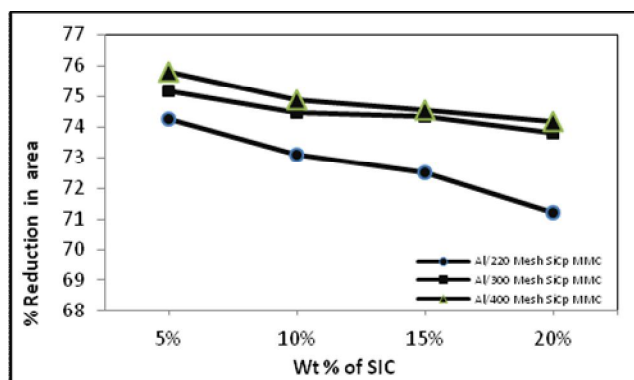


Fig. 13. % Reduction in area Vs Wt.% of SiC

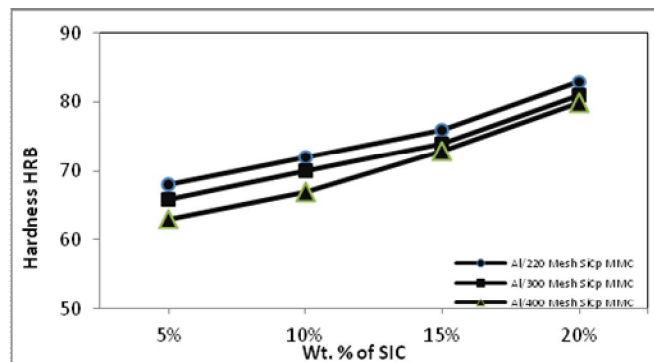


Fig. 14. Hardness (HRB) Vs Wt.% of SiC

## 5. CONCLUSION

The experimental study reveals following conclusions:

- Microstructure:** Optical micrographs showed reasonably uniform distribution of SiC particles and this is good agreement with earlier work. Homogenous dispersion of SiC particles in the Al matrix shows an increasing trend in the samples prepared by applying stirring casting technique.
- Tensile Strength:** From the result graphs Proportionality (MPa) limit, Tensile strength upper yield point (MPa), Tensile strength lower yield point (MPa), Ultimate tensile strength (MPa) and Breaking strength (MPa) increases with the increase in reinforced particulate size (220 mesh, 300 mesh, 400 mesh) and weight fraction (5%, 10%, 15%, 20%) of SiC particles. % Elongation and % Reduction in area decreases with the increase in reinforced particulate size (220 mesh, 300 meshes, 400 mesh) and weight fraction (5%, 10%, 15%, 20%) of SiC particles.

## REFERENCES

- Hashim, J., Looney, L. and Hashmi, M.S.J.. **Particle Distribution in Metal Matrix Composites**, Part-I, *Journal of Materials Processing Technology*, 123: pp. 251\_257, 2002.
- Nather, S., Brabazon, D. and Looney, L. **Simulation of the Stir Casting Process**, *Journal of Materials Processing Technology*, 143\_144: 567\_571, 2003.
- Nai, S.M.L. and Gupta, M. **Synthesis and Characterization of Free Standing, Bulk Al/Sicp Functionally Gradient Materials: Effects of Different Stirrer Geometries**, *Material Research Bulletin*, 38: 1573\_1589, 2003.
- Hashim, J., Looney, L. and Hashmi, M.S.J. **Metal Matrix Composites: Production by the Stir Casting Method**, *Journal of Materials Processing Technology*, 92\_93: 1\_7. 1999.

5. Manna, A. and Bhattacharyya, B. **Study on Different Tooling Systems during Turning for Effective Machining of Al/SiC-MMC**, *The Institution of Engineers (India) Journal-Production*, 83: 46\_50, 2003.
6. Allison, J.E. and Cole, G.S. **Metal Matrix Composite in Automotive Industry: Opportunities and Challenges**, *Journal of Mechanical Science*, 19\_24. 1993.
7. Surappa, M.K. **Microstructure Evolution during Solidification of DRMMCs: State of the Art**, *Journal of Materials Processing Technology*, 63: 325\_333. 3078 A. MANNA ET AL. 1997.
8. Yang, J., Pickard, S.M., Ctedy, C., Evans, A.G. and Mehrabian, T. **The Stress/Strain Behavior of Aluminium Matrix Composites with Discontinuous Reinforcements**, *Acta Metallurgica Materialia*, 39: 1863\_1870. 1991.
9. Lloyd, D.J., Lagace, H., Mcleod, A. and Morris, P.L. **Micro Structural Aspect of Aluminium Silicon Carbide Particulate Composites Produced by a Casting Method**, *Materials Science and Engineering*, A107: 73\_79. 1989.
10. Guo, Z., Xiong, J., Yang, M. and Li, W. **Microstructure and Properties of Tetrapod-like ZnO Whiskers Reinforced Al Matrix Composite**, *Journal of Alloy and Compounds*, 461: 342\_345, 2008.
11. Sulaiman, S., Sayuti, M. and Samin, R. **Mechanical Properties of the As-Cast Quartz Particulate Reinforced LM6 Alloy Matrix Composites**, *Journal of Material Processing Technology*, 201: 731\_735, 2008.
12. Zhou, W. and Xu, Z.M. **Casting of SiC Reinforced Metal Matrix Composites**, *Journal of Materials Processing Technology*, 63: 358\_363, 1997.
13. M.K. Surappa. *J. Mater. Fabrication of Al-Al<sub>2</sub>O<sub>3</sub>/Grp Metal Matrix Composites 3079 Proc. Tech.* 63, pp. 325-333, 1997.
14. D.M. Skibo, D.M. Schuster, L. Jolla, **Process for preparation of composite materials Containing nonmetallic particles in a metallic matrix, and composite materials made by**, *US Patent No. 4 786 467*, 1988.