International Journal of Mechanical Engineering and Robotics Research

ISSN 2278 – 0149 www.ijmerr.com
Vol. 3, No. 4, October 2014

Research Paper

FABRICATION AND STUDY OF MECHANICAL PROPERTIES AND MICROSTRUCTURE OF AL 6063-SICP MMC

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The attractive characteristics, strength as well as weight ratio makes the extensive research on Al-SiCp MMC is carried out globally because of it is widely used in automotive & aerospace industries. However, the behaviour of Al with different percentages of Sicp combined action together with wetting agents. The present study investigates with the mechanical properties and microstructure of Al-alloy with 5%, 10%, 15% weight of Sicp. The compositions were added up to the ultimate level at electrical furnace & used for the fabrication of the aluminium metal matrix composites. The fabricate material is to study of composition of Sicp. The fabricate material is to test on BHN, ROCKWELL, HARDNESS, TENSILE, TORSION, & IMPACT to get mechanical properties at different composition of SICp.

Keywords: MMC, Sicp, Stir casting process. Mechanical properties, microstructuresystem (FMS), Incoming job priority, Slack per Remaining Operations (S/RO)

INTRODUCTION

The increased demand of light weight materials with high strength to weight ratio in the aerospace and automotive industries has led to the development and use of Al-alloy-based composites (mainly Al alloy/SiCp composites). The Metal Matrix Composites (MMCs) are slowly replacing the general light metal alloy such as aluminium alloy in different industrial application where strength, low weight and energy savings are the most important criteria. The combination of various properties like electrical, mechanical, and even chemical can be achieved by use of different types of reinforcements, i.e., continuous, discontinuous, short, whiskers, etc., with the MMCs (Lee J A and Mykkanen D L, 1987 and Ibrahim I A *et al.*, 1991). SiC particles can readily be processed using different machining techniques like extrusion, pressing, rolling, etc., and very much compatible with aluminium matrix. Dry wear, friction properties, tool wear, and surface roughness of Al2O3 reinforced Al alloy MMC have been studied in the article of Akbulut *et al.* (1998) and Sahin *et al.* (2002), respectively. But a limited number of

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investigations have been done to study the abrasive behaviour of ceramic particles reinforced Al-alloy composite. One such investigation has been done in the article of Prasad (Ref 5) where the combined effect of high load and coarse abrasive size has been studied using Zn-Al alloy/SiC_p composites. The two-body abrasive wear behaviour of a cast Al-alloy and 10 wt.% Al_2O_3 particle composite was studied by Mondal *et al*. (1998) at different loads (1 to 7 N) and abrasive sizes (30 to 80 lm).

EXPERIMENTAL SETUP

The MMC, using 6061 Al-alloy (Al-Si-Mg alloy) as the base metal and 10% volume fraction (Vf) of SiCp particles as reinforcement material was prepared by Vortex Method. Though there are several fabrication techniques available to manufacture MMC materials has been described by Naher *et al*. (2004), depending on the choice of matrix and reinforcement material, the fabrication techniques can vary considerably. Fabrication methods can be divided into three types. These processes have been discussed in the article of Skibo *et al*. (1988), i.e., solid phase processes, liquid phase process, and semisolid fabrication process. Solid state processes are generally used to obtain the best mechanical properties in MMCs, particularly in discontinuous MMCs. This is because segregation effects and inter metallic phase formations are less for these processes, when compared with liquid state processes. The advantages of using Vortex method (also known as stir casting) lies in its simplicity, flexibility, highly economical when compared to other processes and also to its applicability to large-scale production. However, it requires optimum process control for mass production. The chemical composition of the base metal and the details of SiC_p are given in Table 1.

Table 1: Impact Test Results in Joules

% of SiC_p	5%	10%	15%
Charpy	7.4	11	18

Preparation of MMC

The particles used for MMC in this study were a type of a- SiC particles with average diameter of 23 lm. The volume fraction of SiC particles added to the melt was restricted to 10%. The reason for using a-SiCp is that it has a high hardness, a low coefficient of thermal expansion and a good wetting property. The SiC particles were mixed and dispersed in the molten 6061 Al-alloy using the Vortex Method. A schematic view of the vortex apparatus used in this process has been presented in Figure 1. The 6061 Al-alloy was melted in a crucible and then stirred at high speed to create a vortex by stainless steel agitator coated with molybdenum using the plasma spray method. The SiC particles were then gradually added and stirred in. During this stage 1-2% calcium was added to the melt as wetting agent. The effect of calcium is that it accumulates in high concentrations in the vicinity of the surface of SiC particles. It

Figure 1: Stircasting Process

reduces the surface tension of aluminium as well as increases the wetting properties of aluminium and SiC. In this way, mixing and dispersion time also reduces a large extent. It was possible to disperse the particles evenly after 60 min of stirring. The whole process of melting and mixing was carried out under an inert atmosphere of argon gas. The conditions used for the vortex-method are presented in Table 2. The important points in these conditions are the temperature of the molten Al-alloy and the speed of the agitator. If the temperature of the molten Al-alloy is too low, it will not be possible to create a vortex and if it is too high, there is the possibility that the SiCp and aluminum will react with each other; the temperature of the molten aluminum was therefore set at 50-100 _C above the melting point. If the stirring speed is too low, it will not be possible to create a vortex and if it is too fast, the added SiC particles will be liable to be scattered, so the optimum speed was maintained at 800 to 1000 rpm throughout the experiments. After dispersing the SiC particles in the molten Al-alloy, the resulting MMC melt was poured into a mold of 60 mm inner diameter where it solidified as a billet. The as-cast billets of 6061Al-alloy/SiCp (particle size = 23 lm and Vf = 10%) of 60 mm diameter and with a hardness value of 46 HB were turned down to 45 mm diameter by machining and Table 1 Chemical compositions of selected material along with volume fraction of SiCp and particle size of SiC_p.

Table 2: Brinell and Rockwell Hardness results in BHN and RCN AT LOAD=150 kgf, BALL=2.5mm

% of SiC_p	5%	10%	15%
Brinell	86	96	15%
Rockwell	16	26	27.5

Figure 2: Test Specimen Pattern Making

Figure 3: Pouring Of Molten Metal into Mould

Heat Treatment

Annealing Process

Annealing is applied to both grades to promote softening. Complete and partial annealing heat treatments are the only ones used for the non-heat treatable alloys. The exception is the 5000 series alloys which are sometimes given low temperature stabilisation treatment and this is carried out by the producer.

Annealing is carried out in the range 300-410°C depending on the alloy. Heating times at temperature vary from 0.5 to 3 hours, conditional on the size of the load and the alloy type. Generally, the time need not be longer than that required to stabilise the load at temperature. Rate of cooling after annealing is not critical.

Where parts have been solution heat-treated a maximum cooling rate of 20°C per hour must be maintained until the temperature is reduced to 290°C. Below this temperature, the rate of cooling is not important.

TESTING

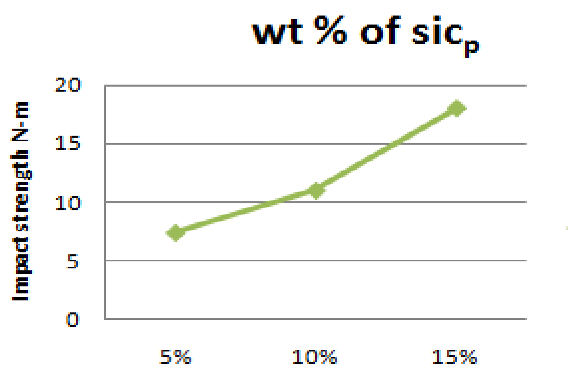
Strength is the material can withstand while being stretched or pulled before failing or breaking.

Charpy Test

This is also known as the Charpy V-notch test, is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's notch toughness and acts as a tool to study temperature-dependent ductile-brittle transition. It is widely applied in industry, since it is easy to prepare and conduct and results can be obtained quickly and cheaply. A disadvantage is that some results are only comparative.

Figure 4: Impact Machine

Figure 5: Impact Load Vs Wt % of sic

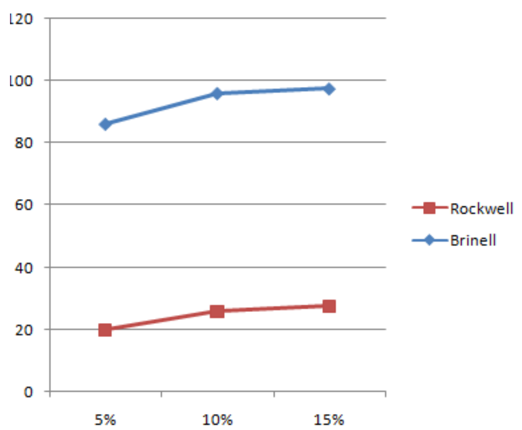


Hardness Test

The brinell hardness test is often easier to use than other hardness tests since the required calculations are independent of the size of the indenter, and the indenter can be used for all materials irrespective of hardness. The basic principle, as with all common measures of hardness, is to observe the questioned material's ability to resist plastic deformation from a standard source. The Vickers test can be used for all metals and has one of the widest scales among hardness tests. The hardness value increases up to 15% weight fraction of SiC and beyond this weight fraction the hardness trend started decreasing. In the hardness test, severe plastic flow has been concentrated in the localized region directly below the indentation, outside of which material still behaves elastically. Directly below the indentation the density of the particles increased locally, compared to regions away from the depression. Although plastic deformation itself has not been responsible for volume change, the existence of very large hydrostatic pressure under the indentation can contribute to volumetric contraction of the metal matrix. As the indenter moves downward during the test, the pressure has been accompanied by non uniform matrix flow along with localized increase in particle concentration, which tends to increase the resistance to deformation. Consequently, the hardness value increases due to local increase in particle concentration associated with indentation up to 15% weight fraction of SiC. Beyond this weight fraction the hardness trend started decreasing as SiC particles interact with each other leading to clustering of

Figure 6: Hardness Test Machine

Figure 7: Brinell and Rockwell Vs Wt % Of Sic_p



particles and consequently settling down. Eventually the density of SiC particles started decreasing locally thereby lowering the hardness.

Torsion

Torsion is the twisting of an object due to an applied torque. It is expressed in Newton metres (N·m). In sections perpendicular to the torque axis, the resultant shear stress in this section is perpendicular to the radius.

Figure 8: Universal Testing Machine

Table 3: Torque Results in N-m

Torsion Test: Torque in N-m

Angle of Twist in ⁰	5%	10%	15%
0-5	3.5	8.5	10
5-10	6.5	17	15.5
10-15	11.5	20.8	18.2
15-20	15	23	19.5
20-25	16.6	25.5	20.8
25-30	17	26.5	21.4

Shear Stress

When Yielding occurs in any material, the maximum shear stress at the point of failure equals or exceeds the maximum shear stress when yielding occurs in the tension test specimen.

Figure 9: Torque (N-m) Vs Angle of Twist In ^{0}

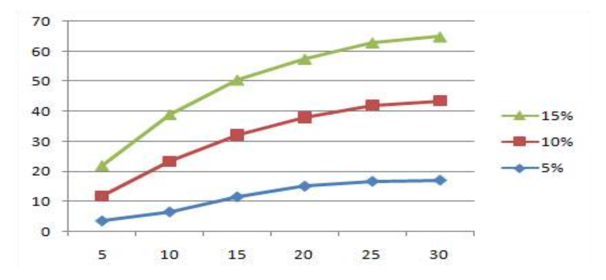
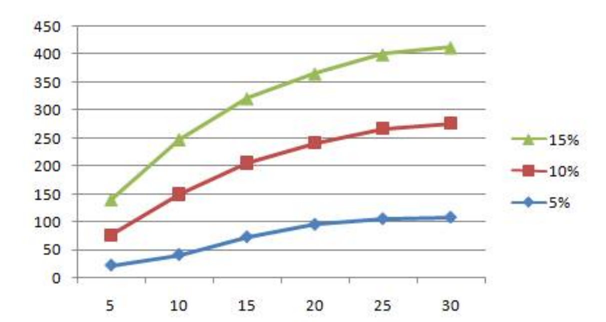


Table 4: Maximum Shear Results in KN/mm²

Angle of Twist in ^{0}	5%	10%	15%
0-5	22.26	54.07	63.61
5-10	41.35	108.15	98.61
10-15	73.16	132.32	115.78
15-20	95.42	146.32	124.05
20-25	105.6	162.23	132.32
25-30	108.15	168.59	136.14

Figure 10: Shear Stress (N-m) Vs Angle of Twist In ^{0}



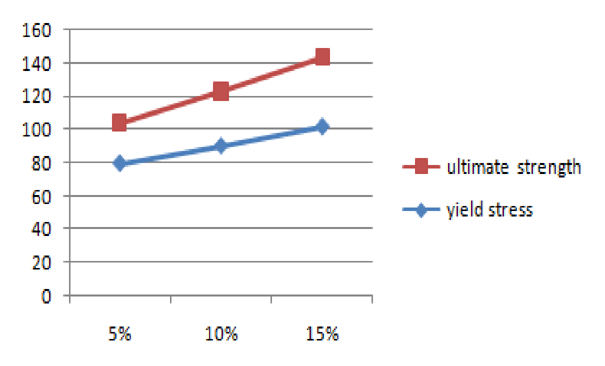
Tensile Test

A tensile test, also known as tension test, is probably the most fundamental type of mechanical test you can perform on material. Tensile tests are simple, relatively inexpensive, and fully standardized. By pulling on something, you will very quickly determine how the material will react to forces being applied in tension. As the material is being pulled, you will find its strength along with how much it will elongate. The universal testing machine (UTM) is used.

Table 5: Ultimate and Yield Results in KN/mm²

	5%	10%	15%
Yield	79.6	90.1	101.7
Ultimate	104.1	122.8	143.5

Figure 11: Ultimate Strength and Yield Stress Vs Wt % of Sic_p



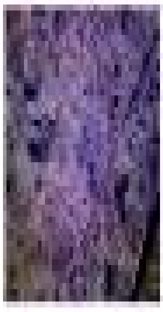
Microstruture

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 X1000). shows Micrograph of Al/Sic-MMC's samples for different Sizes and weight fraction (5%, 10%, 15%,) of SiC particles. Optical micrographs showed reasonably uniform distribution of SiC particles. In this Al matrix SiC particles are clearly labeled.

Before Heat Treatment

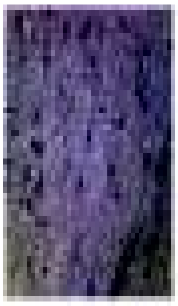
Al with 5% SICp

Al with 10% SICp

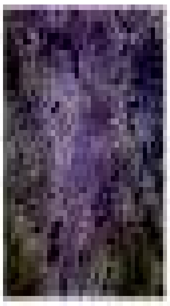


Al with 15% SICp

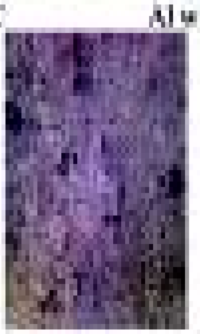
After Heat Treatment



Al with 5% SIC



Al with 10%SICp



Al with 15% SICp

RESULTS AND DISCUSSION

Effect of size and weight fraction of Al6063/ SICp-MMC's on mechanical properties like Shear strength (MPa), Ultimate tensile strength (MPa), Impact Strength (J/mm^2),Hardness number at various percentages of SICp such as 5%,10% and15% are as follows.

Table 6: Maximum Values of the Results

Mechnical Properties	SIC_p		
	(5%)	(10%)	(15%)
Shear strength(mpa)	108.5	168.59	136.59
Impact strength(J/mm^2)	7.4	11	18
Ultimate strength(mpa)	104.1	122.8	143.5
Rock well	16	26	27.5
Brinel hardness	86	96	97.5

CONCLUSION

a. The results of study suggest that with increase in composition of SiC, an increase in hardness, impact strength and normalized displacement have been observed.

b. The best results has been obtained at 15% weight fraction of 320 grit size SiC particles. Maximum Hardness = 82 BHN & Maximum Impact Strength = 18 N-m.

c. Homogenous dispersion of SiC particles in the Al matrix shows an increasing trend in the samples prepared by without applying stirring process, with manual stirring and with 2-Step method of stir casting technique respectively.

REFERENCES

1. Akbulut H, Durman M and Yilmaz F (1998), "Dry Wear and Friction Properties of d-Al2O3 Short Fiber Reinforced Al-Si (LM 13) Alloy Metal Matrix Composites", *Wear*, Vol. 215, Nos. 1–2, pp. 170-179.

2. Basavarajappa S, Chandramohan G and Paulo D J (2008), "Some Studies on Drilling of Hybrid Metal Matrix Composites Based on Taguchi Techniques", *J. Mater. Process. Technol.*, Vol. 196, pp. 332-338.

3. Deuis R L, Subramanian C and Yellup J M (1996), "Abrasive Wear of Aluminium Composites—Review", *Wear*, Vol. 201, pp. 132-144.

4. Ibrahim I A, Mohamed F A and Lavernia E J (1991), "Particulate Reinforced Metal Matrix Composite Review", *J. Mater. Sci.*, Vol. 26, pp. 1137–1156.

5. Lee J A and Mykkanen D L (1987), "Metal and Polymer Matrix Composites", Noyes Data Corporation, Park Ridge.

6. Mondal D P, Das S, Jha A K and Yegneswaran A H (1998), "Abrasive Wear of Al Alloy-Al2O3 Particle Composite: A Study on the Combined Effect of Load and Size of Abrasive", *Wear*, Vol. 223, No. 1, pp. 131-138.

7. Mukhopadhyay S K (1997), ''Development of a Non-conventional Method for Near Net Shape Manufacturing of Light Engineering Components of Circular Geometry'', Ph.D. Thesis, NIT, Durgapur.

8. Naher S *et al.* (2004), "Development and Assessment of a New Quick Quench Stir Caster Design for the Production of Metal Matrix Composites", *J. Mater. Process. Technol.*, Vol. 166, pp. 430-439.

9. Prasad B K (1996), "Abrasive Wear Characteristic of Zinc Based Alloy and Zinc Alloy/Sic Composite", *Wear*, Vol. 252, Nos. 3–4, pp. 250-263.

10. Ravikiran A and Surappa M K (1997), "Effect of Sliding Speed on Wear Behaviour of A356 Al-30wt.% SiCp MMC", *Wear*, Vol. 206, pp. 33-38.

11. Sahin Y (2003), "Wear Behaviour of Aluminium Alloy and its Composites Reinforced by SiC Particles Using Statistical Analysis", *Mater. Des.*, Vol. 24, pp. 95-103.

12. Sahin Y (2005), "Optimization of Testing Parameters on the Wear Behavior of

13. Metal Matrix Composites Based on the Taguchi Method", *Mater. Sci. Eng. A*, Vol. 408, pp. 1-8.

14. Sahin Y, Kok M and Celik H (2002), "Tool Wear and Surface Roughness of Al2O3 Particle-Reinforced Aluminium Alloy Composites", *J. Mater Process. Technol.*, Vol. 128, No. 1, pp. 280–291.

15. Skibo M *et al.* (1988), "Structure and Properties of Liquid Metal Processed SiC Reinforced Aluminium", *Proceedings of the World Materials Congress*, Chicago, pp. 257-262.

16. Zhang Z F, Zhang L C and Mai Y W (1995), "Wear of Ceramic Particle-Reinforced Metal-Matrix Composites Part I, Wear Mechanisms", *J. Mater. Sci.*, Vol. 30, pp. 1961-1966.

17. Zhang Z F, Zhang L C and Mai Y W (1995), "Wear of Ceramic Particle-Reinforced Metal-Matrix Composites Part II, A Model of Adhesive Wear", *J. Mater. Sci.*, Vol. 30, pp. 1967-1971.

18. Zhang Z, Zhang L and Mai Y W (1996), "The Running-In Wear of a Steel/ SiCp-Al Composite System", *Wear*, Vol. 194, pp. 38-43.