

Fabrication and Characterization of Sic Reinforced Al-6Si-0.4Mg Alloy Composites

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ABSTRACT: In this investigation, A356 (Al-5.5%Si-0.5%Mg) alloy/SiCp composites with various weight fractions (0%, 4%, 8%, 10%) were prepared by using permanent mould casting. In addition, A356 alloys were cast for comparison purposes. Microstructure and mechanical properties of these composites were evaluated and compared with as-cast alloy. In addition, tribological properties of these composites were evaluated using a Pin-on-Disc apparatus at a constant sliding velocity of 1m/s and pressure of 0.35 MPa. The microstructure of the composites shows homogenous distribution of SiC particles in the Al matrix. The wear and mechanical properties of composites improve with increasing the weight percentage of SiCp. Particularly, mechanical properties of the A356/10%SiCp composite are higher compared to other weight fractions. Wear morphology studies show that higher wear rate in case of unreinforced specimen was associated with higher thickness of hardened layer and consequent delamination of wear debris from the surface which was confirmed by optical micrography. The present paper highlights the salient features of casting technique and characterization of aluminium alloy A356 metal matrix composite.

KEYWORDS: Permanent mould casting, Sliding Velocity, Reinforcement, Tribology

I.INTRODUCTION

Aluminium-Silicon alloys are known for their excellent combination of characteristics namely, low density, excellent castability, formability, good mechanical properties, cryogenic properties and good machinability and have wide range of applications particularly in Automobile, Aerospace and Marine sectors on account of their light weight, good surface finish, resistance to wear and corrosion and high strength-to-weight ratio. As components with complex geometries can be produced cost effectively, they find enhanced utility particularly in Automobile Aerospace sectors. Large aluminium extrusion components can be produced with lesser number of joints, resulting in less welding. Reduction in weight due to low density leads to increased load capacity, increased mileage, reduced pollution of environment and higher profits to the manufacturers. The low melting temperature, ease of handling, easy formability, easy recycling has led to increased demand for aluminium alloy/composite components.

Pradeep K. Rohatgi [1] studied on the world-wide increase in MMC research and development activities in particularly on cast MMC. The prospective for extensive application of cast composites is very large in India, particularly in the areas of transportation, energy and electromechanical machinery. The wide-range use of composites can lead to large savings in materials and energy, and in several instances, reduce environmental pollution. Honnaiah et al. [2] studied the particle size effects on A356/Al₂O₃ composites. It was observed from the studies that small size particles are superior to large size particles in improving the wear resistance of the composites. Avinash et al. [3] studied A357/Al₂O₃ composites with various volume fractions were prepared by using permanent mould casting. The alloys

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and composites were given a T6 heat treatment process, moreover microstructure, hardness and tensile properties of these composites were evaluated and compared. It was found from the studies that the composites show better wear resistance at all volume fractions compared to the A357 alloy, whereas Wear morphology studies show that abrasive and delamination wear are extensive in the alloy whereas the slight delamination wear with some abrasive grooves are found in the composites. Garcia et.al [4] studied on abrasive wear resistance of A357/Al₂O₃, A339/Al₂O₃, and A6061/Al₂O₃ composites. The composites are fabricated by using compo-casting techniques. They used different particle size and volume fraction. It was observed that abrasive wear increases with decreasing particle size. It was also found that abrasive wear resistance depends upon the matrix bonding with alumina particle. It was observed from the studies that mechanical properties of the composite increased with an increase of volume fraction of SiC in the alloy. Studies on processing and properties evaluation of cast Al matrix reinforced composites are limited. In the present work fabrication and characterization of A356/SiCp MMCs, Micro structural, Mechanical and Tribological Properties are studied.

II. MATERIALS AND METHODS

2.1 COMPOSITE MATERIALS FABRICATION

Cast aluminium alloy A356 Al-Si of known materials was used and SiC particles were used for the reinforcement materials. Some of the properties of matrix and reinforcement material are given in the table 1 and 2 respectively. SiC of average particle size ~60µm has been selected for the present investigation. Three types of composites were fabricated using permanent mould die casting. In addition, the alloy was also cast for comparison purposes. The mechanical properties of Alumina, designation of the alloy and composites is given in Table 3 and Table 4 respectively.

Table 1: Chemical Composition of A356 Table 2: Properties of A356

Element	Weight %
Si	5.5
Mg	0.5
Fe	0.15
Cu	0.05
Mn	0.03
Ti	0.2
Zn	0.05
Others	0.028
Al	Balance

Properties	Values
Density	2.65g/cc ³
Melting Point	554-610°C
Thermal Conductivity	148W/m-K
Elastic Modulus	72.2GPa
Poisson Ratio	0.30

Table 3: Properties of Silicon Carbide Table 4: Designation of Alumina reinforced Alloy

Properties	Values
Density	3.21 g/cc ³
Melting Point	2730°C
Poisson Ratio	0.14
Elastic Modulus	410GPa
Poisson Ratio	0.21

Sl. No	Alloy /Composite	Alloy Designation
1	As cast A356.0	Ac
2	A356.0 +4% SiCp	4S
3	A356.0 +8% SiCp	8S
4	A356.0 +10% SiCp	10S

Large ingots of A356 of required quantity were cut into small pieces for accommodating into the melting crucible. The furnace is to be switched on and set to a temperature of about 850°C and heating is continued for about 3 hours. The SiC particles were preheated to 1200°C for about 2 hour in another furnace. Slag remover is added to the molten metal

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to remove the slag. Hexachloroethane tablets were added to remove gasses entrapped during melting and Magnesium is to be added to the melt to improve the Wettability. Stirrer is immersed up to certain height ($\sim 2/3^{\text{rd}}$) of the molten metal and started the stirring action and at the same time SiC powder is added slowly and stirring action is carried up to 10 minutes. After stirring the molten composite metal is poured into pre heated mould and then the mould is allowed to cool at room temperature, the casted composite material is taken out, by opening the mould halves.



Figure 1: MMCs by casting route through Stir Casting method.

2.2 MICROSTRUCTURE

The specimens for microstructure were prepared as per standard metallurgical procedures, etched in etchant prepared using 90 ml water, 4 ml HF, 4 ml H₂SO₄ and 2g C₁O₃ and photographed using Optical Microscope.



Figure 2:(a) Nikon Microscope LV150 withMetallite image analyser (b) Polished Specimens

2.3 HARDNESS TEST

The hardness tests were conducted as per ASTM E10 norms using Brinell Hardness Tester, where the tests were performed at randomly selected points on the polished surface of samples by providing sufficient space between indentations and distance from the edge of specimen.



Figure 3: (a) Brinell hardness Tester(b)Hardness Test Specimen

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2.4 TENSILE TEST

Tensile properties of materials were tested in Tensometer. The gauge length and diameter of samples are 16mm and 8 mm respectively. UTS and % Elongation were obtained by carrying out an average of 5 trails each and tabulated.



Figure4:(a)Tensometer (b)Tensile Test Specimen

2.5 WEAR TEST

Dry sliding Wear tests were carried out at room temperature using Pin-on-Disc apparatus for varied loads and sliding distances. The wear rates were evaluated using weight loss method by dividing the loss of weight of specimen by the sliding distance for a known sliding time. The loss of weight was measured using an Electronic balance to the accuracy of 0.0001gm. The wear rate was based on the average value of 5 test results. During test, the load was increased gradually till seizure, indicated by high temperature rise; abnormal wear and vibration in Pin-disc assembly were observed. The worn surfaces were further analyzed for type of wear.



Figure 5: (a) Wear Testing Machine (Pin-on-Disc apparatus) (b) Wear Test Specimens

III. RESULTS AND DISCUSSIONS

The microstructure shows distribution of the primary dendrite alpha phase (Aluminium rich phase) in as-cast alloy which is predominant in the matrix. It clearly shows homogenous distribution of SiC particles.

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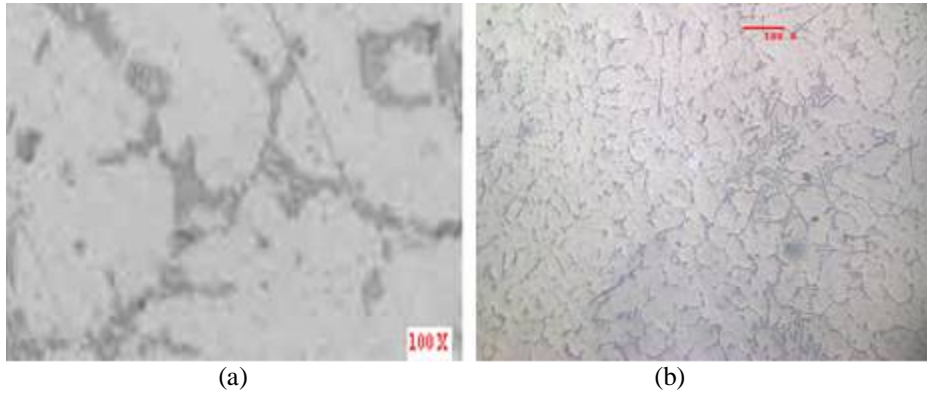


Figure 6: (a) Microstructure of as-cast (b) Microstructure of 4S

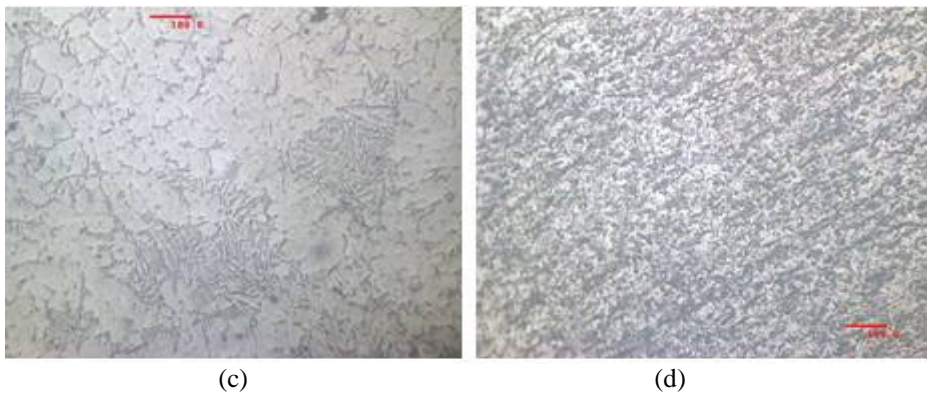


Figure 6: (c) Microstructure of 8S (d) Microstructure of 10S

3.1 MECHANICAL PROPERTIES

The mechanical properties such as hardness, tensile (UTS, % Elongation) obtained as averages of several trials (5 trials) are presented in the Figures below:

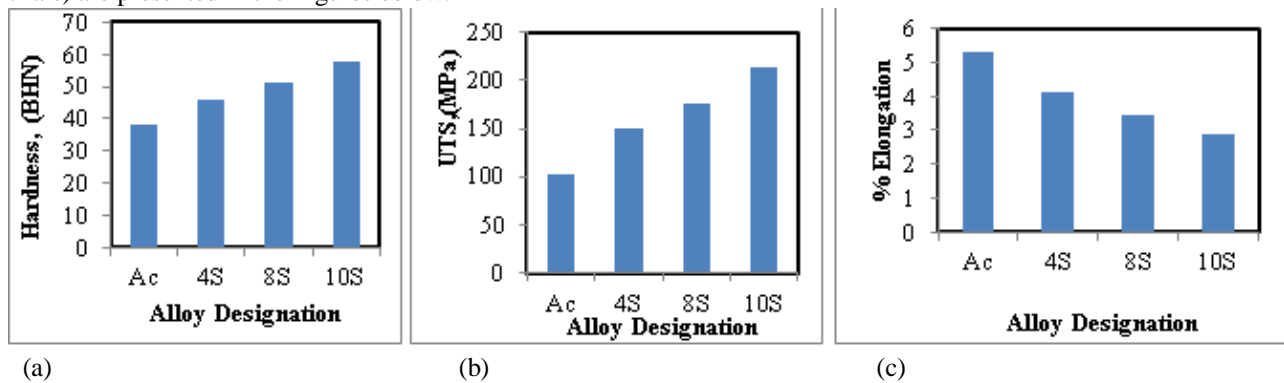


Figure 7: (a) Hardness values of as-cast and its composites (b) UTS values of as-cast and its composites (c) Elongation values of as-cast alloy and its composites

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From Figure 7(a) it is found that hardness increase with increasing SiCp (Silicon Carbide) content in the material. As compared to as-cast (A356 alloy), 4% SiCp addition shows an increase of 8 BHN (~21%). In contrast 8% and 10% SiCp addition shows an increase of 13 BHN (~34%) and 20 BHN (~52%) respectively. This increase in hardness is expected since Silicon Carbide particles being hard add to hardness of the composite. It is clear from the results that the addition of Silicon Carbide particles improves strength and hardness of composites showing maximum hardness in 10S. Figure 7(b) shows plot of UTS of as cast and its composites. Addition of 4% SiC, 8% SiC and 10% SiC shows an increase in 46.28%, 71.38% and 108.75% UTS compared to as-cast respectively. The increase in strength is not proportionate with corresponding increase in hardness this can be attributed improper stirring during the casting of composite. Figure 7(c) shows the plot of ductility of A356 and its composites. The ductility of the alloy lies between 2.88-5.32 percent. From results, it can be seen that most optimal reinforcement amount of SiC in A356 matrix is 10%.

3.2 WEAR PROPERTIES

Figure. 8 shows the plot of Wear rate versus sliding distance of A356 alloy and its composites. It can be seen from the figure that composite has a better wear resistance than the as-cast. The reduction in wear rate may be ascribed to the increase in hardness achieved due to uniform distribution and bonding of the SiCp in the composite.

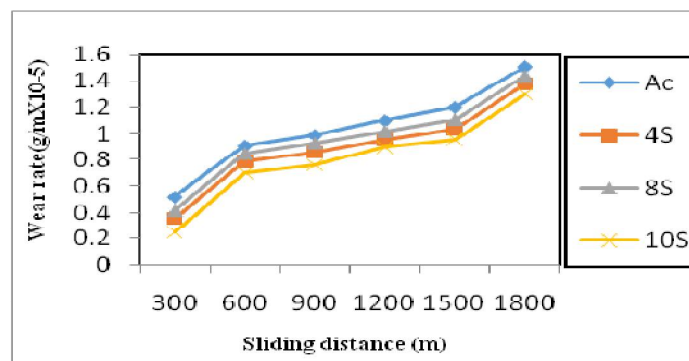


Figure 8: Wear rate of as-cast alloy and its composites

IV. CONCLUSIONS

In the present investigation, A356 /SiCp composites with various weight fractions (0%, 4%, 8%, and 10%) were fabricated and studied for their mechanical and tribological properties. It was found that the wear resistance, hardness and tensile properties of composites increase with an increase of particle weight fraction of SiCp

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BIOGRAPHY



Sajjan Raj Keshari currently pursuing Bachelor of Engineering in Mechanical stream (2012-2016 batch) NMIT which is located in Bengaluru, Karnataka. Material science and manufacturing has been the main area of interest along with composite materials. He has successfully completed internship at Indian Institute of Science, Bangalore in 2015 on the study of microstructures in friction stir processed material.



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