Mechanical Properties of Aluminum A357 Metal Matrix Composite Reinforced with Triple Size Silicon Carbide and Graphite

Yathiraj K, Dr. M.H. Annaiah

Abstract: The research examines the mechanical properties of aluminum A357 metal matrix composite reinforced with silicon carbide at constant 5% wt% and different grain size of 80 µm, 100 µm and 120 µm. The mechanical properties i.e. hardness and tensile strength were studied by preparing the required samples as per ASTM standards by stir casting method. From the obtained results we found that sample with more weight percentage of 120 µm SiC, tensile strength and hardness increases. Also microstructure shows the uniform distribution of reinforcement material.

Keywords: Aluminium matrix composites (AMC), A357, Silicon Carbide, Graphite, Reinforcement, Tensile strength, Hardness.

1 Introduction

Aluminium matrix composites (AMCs) are proved to be better substitutes comparing with the conventional aluminium alloys because of their improved strength to weight ratio, energy saving, better wear resistance etc. AMCs reinforced with particles of Gr have been reported to be possessing better wear characteristics owing to the reduced wear because of formation of a thin layer of Gr particles, which prevents metal to metal contact of the sliding surfaces.

Different types of reinforcement play a vital role in the various characteristics of the MMCs. The most commonly used reinforcements are Silicon Carbide (SiC) and Aluminium Oxide (Al2O3). SiC reinforcement improve the tensile strength, hardness, density and wear resistance of Al and its alloys while the Al2O3 reinforcement increases compressive strength and wear resistance. Boron Carbide (B4C) is one of the hardest known elements which have high elastic modulus and fracture toughness. The addition of B4C in Al matrix increases the hardness, but does not significantly improve the wear resistance. Zircon is usually used as hybrid reinforcement. It significantly improves the wear resistance. The use of fly ash reinforcements has been increased in the last decade due to their low cost and availability as by-product in thermal power plants. Fly Ash improves the electromagnetic effect of the Al-MMC significantly. Based on the various benefits of MMCs, this paper studies the behaviour of Silicon Carbide reinforcement materials on the Aluminium based MMCs.

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In [1] investigated the microstructure of as-cast plates fabricated by Al6061/SiCp MMC by a low cost stir casting technique using SiC particles in a varying weight percentage of 5, 10, and 15%. The microstructure investigation carried out using Optical microscopy, X-ray diffraction (XRD) analysis and Wavelength dispersive X-ray fluorescence spectroscopy (WD-XRF) showed excellent distribution of SiCp in to 6061Al alloy matrix. Moreover, XRD analysis reveals the uniform presence of SiC particles into matrix.

In [2] studied the mechanical properties of Al-6061/SiC (Silicon carbide) MMCs by STIR casting process. The composite plates were prepared with varying the reinforced particles by weight fraction of 5%, 10% and 15%. The average reinforced particles size of SiC was 325 mesh respectively. The stirring process was carried out at 200rev/min rotating speed. The results showed that addition of silicon carbide particles to the matrix alloy improves the mechanical properties such as hardness and tensile strength of the matrix alloy. But the wear rate tends to decrease with increasing particles wt. percentage.

In [3] investigated the dry sliding wear behaviour of aluminium 5059/SiC/MoS2 hybrid metal matrix composites using silicon carbide (SiC) (5, 10%, 15%) and particle size (10, 20,40µm) of SiC and constant 2% of Molybdenum disulphide(MoS2) is reinforced with aluminium matrix. The experiments were conducted by varying the sliding speed of (1.5,2.5 &3.5 m/s), loads (30,50&70N) with sliding distance ranges from (500, 1000& 1500m) under dry sliding conditions. Taguchi method and ANOVA method was used to find out the outcome which showed that load and sliding distance are the most influencing factors for friction coefficient also Load and percentage of SiC indicates the most affecting factor for wear rate. It was also concluded that 15% weight percentage of SiC at 10µm offers better wear resistance and friction coefficient.

In [4] fabricated aluminum alloy AlMg0.7Si-SiC metal matrix composites and used taguchi optimization approach for inspection of wear performances. The AMCs are fabricated (having 37µm SiC particle size) in four different wt. fractions (0 wt%, 3.5 wt%, 7 wt% and 10.5 wt %). Effect of three control variables, viz,. % wt. of SiC, Load (N) and Sliding distance (m) on the wear rate and frictional force of the casted composites in unlubricated dry slippery conditions is examined by using pin-on-disc wear and friction monitor apparatus. And analyzed that sliding distance is the most significant factor influencing wear rate.

In [5] developed the aluminum based silicon carbide composite in order to study the effect of silicon carbide particles on mechanical and tribological properties of A357 metal matrix composites. SiC (100 grit) was selected and experiments were conducted for varying percentage of SiC (from 0%-12% in the steps of 3%). The experimental results showed that tensile and hardnes increased with increase in SiC weight percentage and also 12% SiC with Aluminium will give the maximum value among the matrix mixture composites.

In [6] studied the tribological properties of Al 6061- micro SiC (5, 10 and 15 wt.%) and Al 6061- nano SiC (0.5, 1.0 and 1.5 wt.%) which were produced by stir casting technique and concluded that aluminium based composite with 1.0% by weight nano SiC reinforcement possess better wear resistance properties compared to micro SiC reinforced aluminium metal matrix composites.

In [7] studied the dry sliding wear behavior of A357 (Al-7%Si) alloy reinforced with the bimodal sizes (~250µm (L) and ~38 µm (S)) of 6wt% SiCp prepared by permanent mould die casting method. In the study three different combinations of bimodal distributions were considered: (3% L + 3% S, 4% L + 2% S, and 2% L + 4% S) and the wear behavior of the alloy and the composites was studied for the speed of 1 m/s and load conditions of 10-30 N with an interval of 5 N in a pin on disc apparatus. The hardness and microstructure of the composites were also characteristised. The results showed that the addition of bimodal size of particles significantly improves the hardness and wear resistance of the alloy. Among the different combinations, the 4% L + 2% S bimodal distribution combination provides the highest wear resistance and the hardness. This result indicates that the higher amount of large size particles are more important than that of small size particles to improve the wear resistance.The wear morphology studies showed that the abrasive wear is the main wear mechanism in the bimodal size composites whereas the delamination wear is predominant in the alloy.

In [8] studied the mechanical and tribological properties of composites made using Al-18wt%Si as the base alloy and SiC particles as the reinforcement. The composite was prepared using stir casting with bottom pouring technique and centrifugal casting. Various mechanical and tribological properties were checked and were then compared with results of the base alloy produced using centrifugal casting. It was found that, the introductions of the SiC particles have improved the mechanical and tribological properties of the base alloy.

In [9] investigated conventional simple methods of producing MMC with attained properties through the dispersion of silicon carbide in the matrix. Two-step mixing method of stir casting technique was employed. Aluminum (99.66 %C.P) and SiC (320 and 1200 grits) were chosen as matrix and reinforcement materials. Experiments were conducted by varying the weight fraction of SiC for 2.5 %, 5.0 %, 7.5 % and 10 %. The result showed that the stir casting method was quite successful to obtain uniform dispersion of reinforcement in the matrix. This was indicated by the improvement of properties of composites over the base metal. Young's modulus (E) and hardness increased in reinforced Aluminum Silicon Carbide composites above the unreinforced case and marginal reduction of electrical conductivity was recorded for the composites. The silicon carbide of 1200 grits (3 µm) showed increased Young's modulus (E) and hardness of 1517.6 Mpa and 26.1 Hv values at 7.5%volume fraction silicon carbide; when compared with the silicon carbide 320 grit (29 µm).

In [10] studied the mechanical properties and microstructure of aluminum alloy 63401 metal matrix composite reinforced with silicon carbide powder of different wt% i.e. 3%, 6% and 9% and different grain size of 177 µm, 149 µm and 74 µm. From the experiments conducted it was concluded that the hardness and impact strength of the Al alloy increased with the increase in percentage of SiC and with the decrease in grain size of SiC. The tensile strength increased by increasing wt % of SiC whereas % elongation decreases with the increase in weight percent of SiC and increases by decreasing grain size of SiC.

2 EXPERIMENTAL METHODOLOGY

The materials which were used in the present research are Aluminum A357, SiC of 5%, weight percentage with grain sizes of 80 µm, 100 µm and 120 µm. Table 1 represents the chemical composition of Al A357 and Table 2 represents the sample composition. Stir casting method used for preparing the samples. For stir casting, the Al A357 was placed in the furnace and melted at a temperature of 800°C. The reinforcment SiC preheated at 400°C. After melting of Al alloy reinforcing material along with 1.5%, weight percentage graphite and grain refiner and modifier were added and stirring was done. After that mixture was poured into the die. After solidification, composites were taken out and machining was done as per ASTM standards.

TABLE 1

CHEMICAL COMPOSITION OF WROUGHT ALUMINUM A357 (PERCENT COMPOSITION)

Element	% Weight Present
Cu	0.020
Mg	0.481
Si	6.775
Fe	0.160
Mn	0.027
Ni	0.030
Pb	0.022
Sn	0.012
Ti	0.152
Zn	0.040
Al	REM

TABLE 2
SPECIMEN COMPOSITION

Sl.No	Designation	Composition
1.	**SAMPLE A**	2% 80 microns, 1.5% 100 microns, 1.5% 120 microns, 1.5% of graphite, and 1.5% of both Strontium and Titanium Boron
2.	**SAMPLE B**	1.5% 80 microns, 2% 100 microns, 1.5% 120 microns, 1.5% of graphite, and 1.5% of both Strontium and Titanium Boron
3.	**SAMPLE C**	1.5% 80 microns, 1.5% 100 microns, 2% 120 microns, 1.5% of graphite, and 1.5% of both Strontium and Titanium Boron

3 RESULT AND DISCUSSION

3.1 Microscopic Study

Microscopic study were conducted using Optical Microscope. From the results obtained we can observe that the reinforcement particles are approximately uniformly distributed. Fig. 1 to Fig. 3 shows the different microstructure of Al A357 reinforced with different percentage of SiC grains.

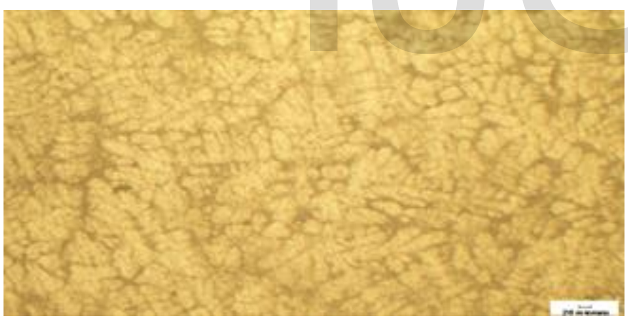

Fig. 1. Microstructure of Sample A

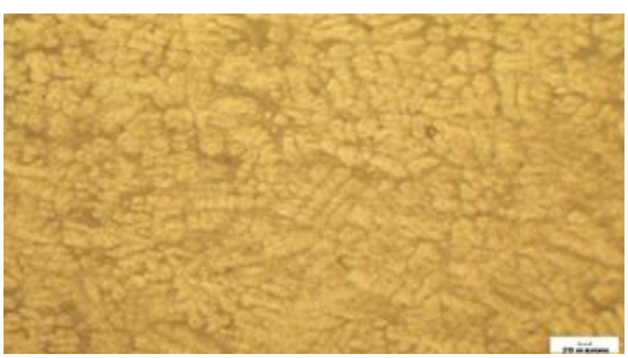

Fig. 2. Microstructure of Sample B

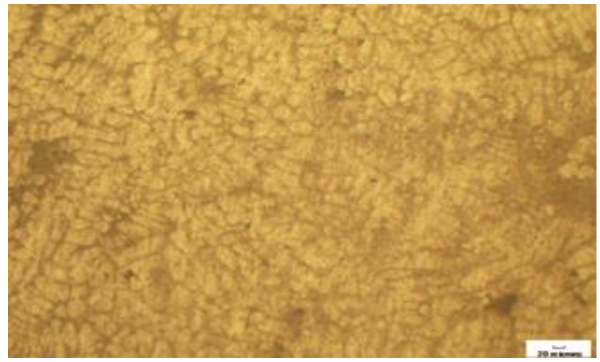

Fig. 3. Microstructure of Sample C

3.2 Hardness Test

Brinell hardness testing method was used in this research at a room temperature. From the Fig. 4 obtained results we found that as we increase the weight percent of SiC at grain size of 120 µm, the hardness of the Al alloy A357 increases. By adding SiC, the hardness also increases. Table 3 represents the result of hardness test with varying grain size of SiC.

TABLE 3
RESULT OF HARDNESS TEST

Sample	Hardness
A	53
B	54.2
C	55.5

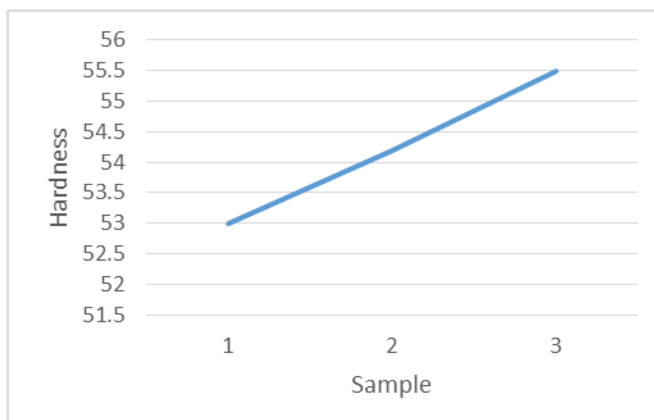

Fig 4. Variation of hardness values

3.3 Tensile Test

The instrument used for tensile testing is TUE-C of capacity 1000 KN. Table 4 represents the value of tensile strength. From the above obtained result from Fig. 5 we found that by increasing wt % of 120 µm SiC at constant grain size, the tensile strength increases.

TABLE 3
RESULT OF TENSILE TEST

Sample	Tensile Strength (N/mm2)
A	164
B	169
C	172

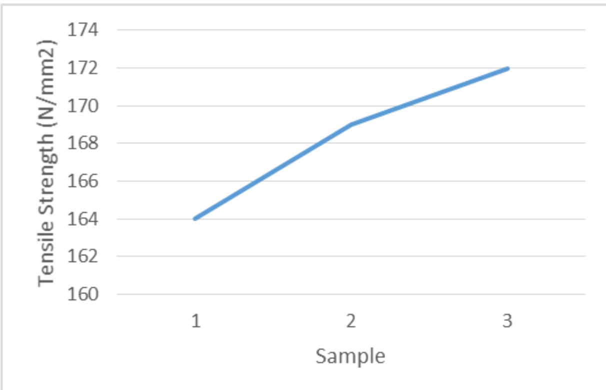

Fig. 5. Variation of Tensile values

4 CONCLUSION

From the above experiment conducted, we can conclude from the obtained result that stir casting method is one of the easiest method which can be used to produce aluminum composites. The hardness and Tensile strength of the Al alloy increases with the increase of 120 microns SiC for constant percentage of SiC.

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