Mechanical Characterization of Al-Sicp– Fly Ash Composites

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***Abstract*-Al-SiC_p-fly ash hybrid metal matrix composites have been prepared by fixing the percentage of SiC_p (5%) and varying the percentage of fly-ash (5%, 10 % and 15% by weight) using stir casting technique. Three cylindrical samples have been prepared of 20 mm diameter. Tensile and compression specimens were made by machining as per standards and tested in Universal Testing Machine for evaluation of strength in tension and length of compression till fracture. Hardness of the specimens was measured by Brinell hardness tester. From the results obtained it has been observed that the tensile strength of these specimens increase with increase in the percentage of fly ash. Similarly the compressive strength also increases as force required for compression is higher for higher percentages of fly ash. Out of the three composites , the composite with 15% fly ash has exhibited reasonable tensile, compressive strengths and moderate hardness. This composite may be used in structural applications where light weight and high strength are the criteria.**

***Key words*- Aluminium, Silicon carbide particles, Fly Ash, Composites, Tensile strength, Compression tests**

I. INTRODUCTION

Hybrid metal matrix composites are gaining a lot of acceptance due to their higher specific strength, specific modulus and good wear resistance as compared to ordinary unreinforced alloys. Aluminium being light weight is widely used in domestic appliances, space and rocketry engineering. The Al-SiCP-Fly ash hybrid composite can be used in automotive engines, piston, rotor, brake and other structural applications which are light weight and high strength materials. Aluminium though a trace element with moderate toxic effect on living organism have poor tribological properties. Hence the need of a new material with better strength, light weight and higher wear and tribological properties led to the development of such metal matrix composites. In the present study, Aluminium metal matrix composites (AMC) reinforced with varying proportion of Fly ash (5, 10 and 15 wt%) and fixed proportion of Silicon Carbide (5 wt%) were manufactured using stir casting process. Silicon carbide, a high temperature resistance material was used as reinforcement material to increase the strength of the composites.

Fly ash a low density reinforcement is easily available as a solid waste by-product of thermal power plant. In this study Fly ash was used as reinforcement to lower the weight of composites due to its low density. AMC increases components life and also lead to economic benefits. In automobile sector, utilization of AMCs lead to fuel economy and lowering of noise. Stir casting method is best suited for manufacturing of AMC s and the reinforcements could be in the form of fibres, whiskers or particulates.

II. REVIEW OF LITERATURE

Metal matrix composites, in particular aluminium matrix composites have drawn the attention of the researchers in the recent years owing to their light weight, easy machinability, soft processing parameters and moderate cost. Further the use of fly ash as reinforcement, produced as waste from coal based power plants has been considered for reduction in environmental pollution and low cost. A lot of research has been done to develop composites with aluminium as matrix material reinforced with silicon carbide particulates or fly ash in varying contents. Therefore a review is essential to acquire knowledge about manufacture of these composites, their mechanical characteristics and specific applications. Harris [1] investigated on different scopes of reinforcements in metals and polymers. Metals with reinforcements are versatile because they can be plastically deformed and can be strengthened by a variety of methods. Few polymers are thermally stable as compared to metals or even more stable like polyamides, which degrade by exposure to temperature above 300^0C. According to him polymers are generally insulators and in their application as such strength is a secondary consideration. Hashim et al. [2] evaluated the relatively low stir casting process for use in the production of silicon carbide/aluminium alloy MMCs. Processing variables such as holding temperature, stirring speed, size of the impeller, and the position of the impeller in the melt are among the important factors to be considered in the production of cast metal matrix composites as these have an impact on mechanical properties. Sahin [3] prepared SiC_P reinforced Al MMC with 10 and 20 wt% of SiC_P as

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reinforcements. Different properties of MMC like density, hardness and porosity were studied. It was found that the hardness of the aluminium alloy improved significantly by addition of SiC particles into it, while density of the composite also increased almost linearly with the weight fraction of particles. However, porosity level increased slightly with increasing particulate content and decreased with increasing particle size. Rao et al. [4] prepared Al (5 to 15 wt %)-Fly ash composite. The microstructural characterization was done by SEM and optical microscopy. The hardness of the composites was found to increase whereas the density of the composites decreased with increasing amount fly ash than pure aluminium. Enhanced mechanical properties were also observed with increasing amount of fly ash under compression. Anilkumar et al. [5] reported experimental investigation of the mechanical properties of fly ash reinforced aluminium alloy (Al 6061) composite samples processed by stir casting route. They used three sets of composites with fly ash particle sizes of 4-25, 45-50 and 75-100 µm. It was observed that the tensile strength, compressive strength and hardness of the aluminium alloy (Al 6061) composites decreased with the increase in particle size of reinforced fly ash. Increase in the weight fractions of the fly ash particles increases the ultimate tensile strength, compressive strength, hardness and decreases the ductility of the composite. They reported that the decrease in the tensile strength of the samples with fly ash weight fraction beyond 15 % is due to the poor wettability of the reinforcement with the matrix. Rao and Padmanabhan [6] studied on Al-Boron carbide composite. The composite was fabricated by liquid metallurgy technique with different weight fraction of particulates (2.5, 5 and 7.5). As per the investigations, with the increase in the amount of the boron carbide, the density of the composites decreased where as the hardness was increased. The ultimate compressive strength of the composites was increased with increase in the weight percentage of the boron carbide in the composites. Prashant et al. [7] compared the mechanical and wear properties of Al6061-Graphite and Al6061-SiC composites. Composites were prepared using stir casting method in which amount of reinforcement was varied from 6-12% in steps of 3wt%. They found that experimental densities were lower than theoretical densities in all the composites. Micro hardness of the Al6061-SiC composite was increased with increased filler content whereas for Al6061-Graphite composite decreased with increased filler content. They found that the wear resistance of the Al6061-SiC composite decrease with increased filler content whereas the wear resistance of the Al6061-graphite composite decreases up to 6wt% but thereafter tends to increase. Ravesh and Garg [8] considered Aluminium 6061 as matrix SiC, Fly Ash as reinforcement materials respectively to make composites. Experiments were conducted by varying weight fractions of SiC (2.5%, 5%, 7.5%, 10%) while keeping all other parameters constant. Observations revealed that there was an increase in the value of tensile strength, hardness and toughness with increase in weight percentage of SiC. Lokesh et al. [9] investigated the value of density, tensile, compressive and hardness properties of Al-Cu alloy reinforced fly ash metal matrix composite. Reinforcement of fly ash in wt percentage of 3%.6%,9% and 12% was done by squeeze casting with an applied pressure of 120 MPa. It was seen that the hardness, tensile, compression and impact values were increased by increasing weight percentage of fly ash reinforcements during squeeze casting. Srivastava et al. [10] investigated that aluminium alloy with reinforcement is a better choice to base alloy. It improves the mechanical properties with their excellent quality of tensile strength, impact strength, wear resistance, hardness and corrosion resistance etc. Fatigue properties of aluminium cast alloy present better results as compared to other materials but sometimes presence of porosity may cause not so much desirable results. It was also concluded that after adding reinforcement to the base metal, electrical and thermal properties are also improved compared to base metal.

III. OBJECTIVES

a. To develop metal matrix composites with varying weight fractions of fly ash, silicon carbide particulates in aluminium matrix.
b. The composites will be manufactured by stir casting process
c. The mechanical characterization of the composites will be carried out in terms of measurement of hardness, tensile strength, compression strength etc. as per standard.
d. Finally based on the results obtained the best material out of these composites will be chosen for specific application.

IV. EXPERIMENTAL METHODS

A. Processing method

The Stir casting method (also called liquid state method) is used for the hybrid composite materials fabrication in which a dispersed phase is mixed with a molten matrix metal by means of mechanical stirring. The liquid composite material is then cast by conventional casting methods and may also be processed by conventional metal forming technologies. Pure aluminum was melted in a resistance furnace.

The Stir casting process was done in the following steps:

a. Pure Aluminium ingot(in proper wt%) was placed in the crucible and melted at 800^{o}C. the reinforcements Fly Ash (11µm size) and SiCp (42 µm size) of proper wt% were preheated to 500^{o}C and maintained at that

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temperature for 20 minutes in the tube furnace to remove moisture content.

b. b.Then the molten metal was stirred to create vortex and the preheated reinforcements were slowly added to the molten metal maintained at 800°C, with continuous stirring at a speed of 350 rpm to a time of 6 minutes.
c. Then the melt with the reinforcements were poured in to the mould.
d. It was left for 3 hrs. to get solidified before withdrawing it from the mould.

Three nos. of samples were manufactured in the stir casting process having different composition (wt %) as listed in the Table I.

TABLE I. Samples And Their Compositions

Sl.No	Composites
1	Al + 5wt% SiC + 5 wt% Fly Ash (C1)
2	Al + 5wt% SiC + 10 wt% Fly Ash (C2)
3	Al + 5wt% SiC + 15 wt% Fly Ash (C3)

B. Density measurement

The densities of different composites as measured experimentally have been shown in Table II.

TABLE II. Densities of the Composites

Sl.No	Composites	Density (gm/cm^3)
1	Al + 5wt% SiC + 5 wt% Fly Ash (C1)	2.65
2	Al + 5wt% SiC + 10 wt% Fly Ash (C2)	2.55
3	Al + 5wt% SiC + 15 wt% Fly Ash (C3)	2.454

It is clear that the density of the composite decreases with the addition of Fly Ash

C. Hardness test

Hardness of the composites have been determined by Brinell hardness tester and values are indicated in Table.III.

TABLE III. Hardness Of Composites

Composites	Hardness(BHN)
C1	22
C2	24
C3	28

D. Tensile test

Standard specimens of 8 mm diameter and 100 mm length and having gauge diameter of 4 mm and 24 mm gauge length were prepared to evaluate the ultimate tensile strength, yield strength and % elongation. The samples for tensile tests are shown in Fig. 1. The tensile testing of standard specimens was done using a computerized UTM (TINIUS OLSEN, model no.-H50KS, 50 KN capacity, Fig.2). The loaded specimen has been shown in Fig. 3.The strain rate was 0.25 mm/min. Online plotting of stress versus strain was done continuously through a data acquisition system.

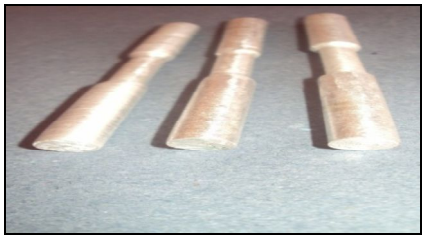


Fig.1 Samples of tensile specimens



Fig.2 The UTM for tensile tests



Fig.3 Specimen loaded in the UTM

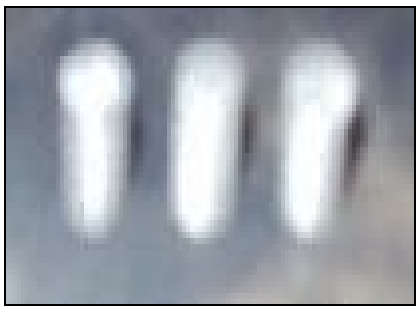


Fig.4 Specimens for compression tests

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E. Compression test

The compression testing was also carried out in a computerized UTM (TINIUS OLSEN, model no.- H50KS). The specimens have been shown in Fig. 4.

F. Optical Micrograph

To obtain better mechanical and wear properties of the composites, it is necessary to distribute the reinforcements uniformly throughout the casting during the preparation of composites. Optical microscopy was carried out to study the distribution of reinforcements after casting. The microstructure of three different composites are shown in the Figures 5, 6 and 7 for different percentages of fly ash contents with 5% SiCp with 200 X magnification.

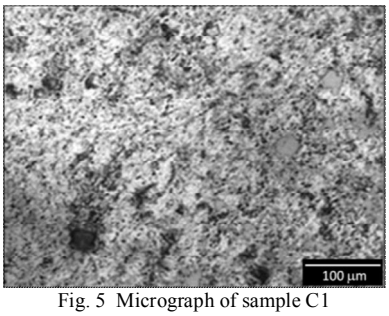


Fig. 5 Micrograph of sample C1

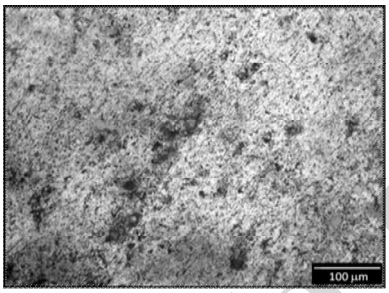


Fig. 6 Micrograph of sample C2

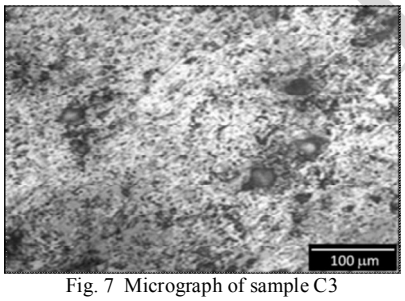


Fig. 7 Micrograph of sample C3

The above three micrographs show the distribution of Fly Ash and SiC_P in the matrix. But there is segregation of the reinforcements at some particular location. To avoid the segragation, magnesium should be added. Also the micrographs reveal some degraded hole and some impurites/slag. If degassifier were used, there would not have been any impurities/slag or it would have been minimized.

VI. RESULTS AND DISCUSSION

The ultimate tensile strengths and yield strengths of the composites obtained from the tests are presented in Table IV.

TABLE IV. Results of Tensile Tests

Composites.	UTS(MPa)	Elongation	Yield Strength
Sample-C1	109	13.3	52.3
Sample-C2	120	18.1	55.8
Sample-C3	120	14.0	115

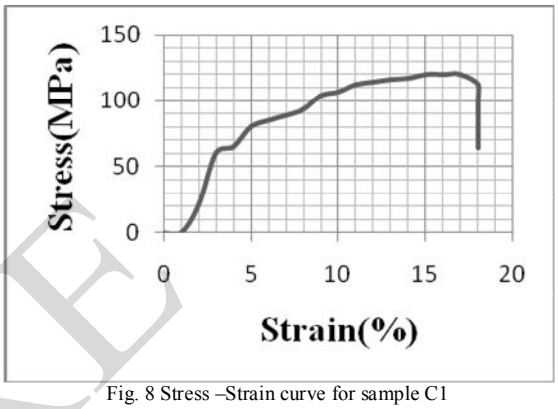


Fig. 8 Stress –Strain curve for sample C1

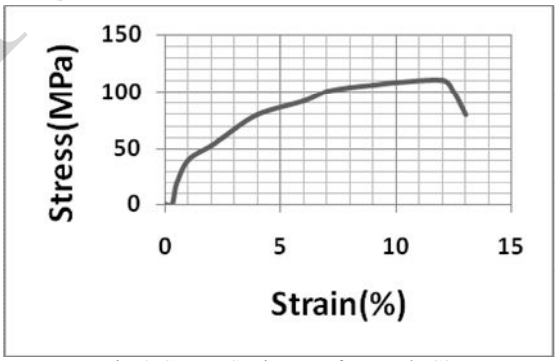


Fig. 9 Stress - Strain curve for sample C2

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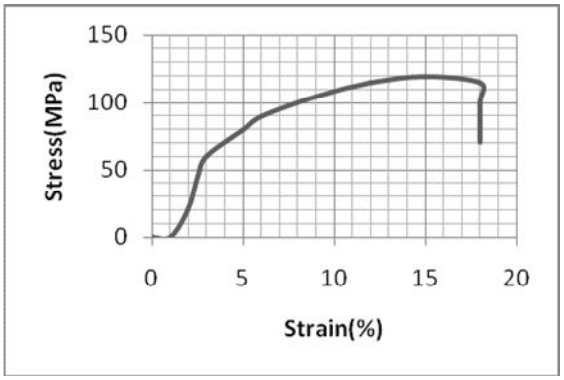


Fig. 10 Stress-strain curve for sample C3

From the stress-strain curves obtained (Fig.8, 9 and 10) for tensile tests it is observed that ultimate tensile strength and yield strengths are increasing with increase in fly ash contents. However elongation for sample C2 is more in comparison to other samples.Similarly the compression strengths of the composites are presented in the Table V.

TABLE V. Compression Strengths of Composites

Composites	Compressive strength (MPa)	Compression(mm)
Sample-C1	170	2.02
Sample-C2	229	2.27
Sample-C3	233.125	3.04

The Force applied versus Compression are also plotted in Fig.11,12 and 13 for all the samples.

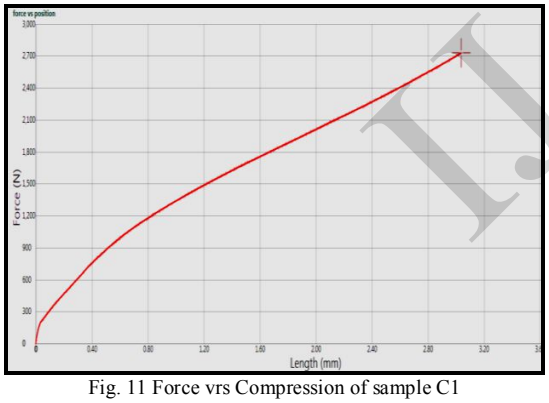


Fig. 11 Force vrs Compression of sample C1

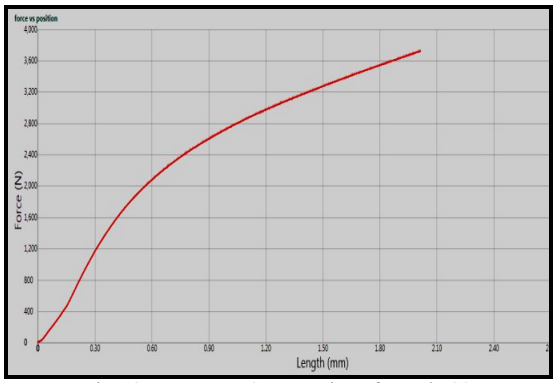


Fig. 12 Force vrs Compression of sample C2

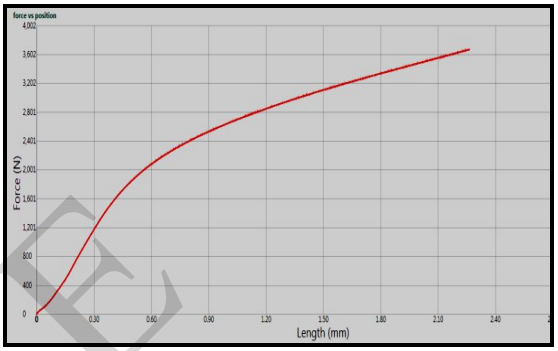


Fig. 13 Force vrs Compression of sample C3

From the compression tests it may be concluded that the compressive strength is increasing with increase in fly ash content and composite with 15% fly ash is having highest compressive strength.

Using stir casting method Aluminium metal matrix composites reinforced with Silicon carbide particle and Fly Ash was successfully fabricated. The composites were prepared by varying the wt% of Fly Ash and keeping the wt% of SiCP constant. The optical micrographs of the cast composites reveal the fair distribution of the reinforcements. From the Brinell hardness test, the hardeness was found to increase from 22 BHN to 28 BHN with increase in the wt% of Fly Ash from 5wt% to 15wt%.The densities of the composites were measured using Archimedi's principle. The density was found to decrease from 2.65 gm/cc to 2.454 gm/cc with increase in wt% of Fly Ash. The ultimate tensile strengths were found to increase from 109 MPa to 120 MPa for the composites. With increase in wt% of Fly Ash from 5wt% to 15 wt% the yield strength was also found to increase from 52.3 MPa to 115 MPa for the same composites. The compression strengths of the composites were found to increase from 170 MPa to 233.125 MPa for the samples from C1 to C3 in order of increasing fly ash percentages.

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VI. CONCLUSIONS

From the results of all the above tests, the composite with 15wt% Fly Ash is having reasonable yield strength with reasonable tensile and compressive strength. Moderate hardness values are also obtained for this composite. It is expected that this composite may be suitable for frictional applications, structural use in aerospace and rocketry engineering including automobile components.

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