Characterization and Production of Al-Cu Alloy Reinforced with Flyash and Silicon Carbide MMCS

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***Abstract*— Considering the wide applications of automotive, aircraft and industrial components, there has been an increasing interest in composites containing low density and low cost reinforcements for making economic productivity as well as better performance. Among various discontinuous disperoids used, fly ash is one of the most inexpensive and low density reinforcement available in large quantities as solid waste by-product during combustion of coal in thermal power plants. Hence, composites with fly ash as reinforcement are likely to overcome the cost barrier for wide spread applications in automotive and small engine applications.**

Aluminium matrix composite which is reinforced with Silicon carbide and fly ash possess increased rate of mechanical properties such as Impact strength, Hardness and Wear resistance. The composites of Aluminium Copper MMC alloys with different compositions of fly ash and Silicon Carbide were produced as test specimens. The results show that these properties increases with increased percentage of reinforcements.

Keywords— Al MMC; Fly ash as reinforcement; SiC particulates

I. INTRODUCTION

Composite materials are the one which is made from two or more materials constituently with significantly different physical and chemical properties and which remain separate and distinct on a macroscopic level with the finished structure. A metal matrix composite (MMC) is composite material with at least two constituent parts, one being a metal as matrix. The other material called as reinforcement may be a material such as a ceramic or organic compound. The reinforcement does not always serve a purely structural task (reinforcing the compound), but is also used to change physical properties such as wear resistance, friction coefficient, or thermal conductivity. For example, Silicon Carbide particle introduced into the metal matrix is beneficial for mechanical strength.

In this present investigation Al-4.5wt%Cu/SiC/Fly-ash hybrid composite is synthesized by stir casting route. The synthesized hybrid composite is then characterized using optical microscope, universal testing machine and pin on disc. Hardness values at each of the selected reinforcement particles are also studied by using Brinell Hardness Tester with a load capacity of 10Kgf to compare the interfacial bonding between the particle–matrix interfaces for different reinforcements. Compression strength is tested in universal testing machine with a load capacity of 60tons. Impact strength was conducted using Izod and charpy tester with a capacity of 50Kgf/m with a hammer velocity of 5m/sec and hammer weight of 37Kgs. A computerized pinion- disc wear test machine was used to conduct wear test. Wear tests were conducted in pin on disc machine with a pin of 10mm diameter and 28mm in length. An ASTM standard was used for conducting all the tests. Scanning Electron Microscope (SEM) and Optical Microscope was used for better analysis of matrix and reinforcements bonding.

A) PHASES OF MATRIX

1) MATRIX PHASE

- The primary phase, having a continuous character.
- Usually more ductile and less hard phase.
- Holds the reinforcing phase and shares a load with it.

2) REINFORCING PHASE

- Second phase (or phases) in the matrix is imbedded in a discontinuous form.
- Usually stronger than the matrix, it is sometimes called reinforcing phase.

B) SILICON CARBIDE (SiC) AS REINFORCEMENT

Silicon Carbide is the only chemical compound of carbon and silicon. It was originally produced by a high temperature electro-chemical reaction of sand and carbon. Silicon carbide is an excellent abrasive and has been produced and made into grinding wheels and other abrasive products for over one hundred years. Today the material has been developed into a high quality technical grade ceramic with very good mechanical properties. It is used in abrasives, refractories, ceramics, and numerous high-performance applications. The material can also be made an electrical conductor and has applications in resistance heating, flame igniters and electronic components. Silicon carbide is composed of tetrahedra of carbon and silicon atoms with strong bonds in the crystal lattice. This produces a very hard and strong material.

C) FLYASH AS REINFORCEMENT

The preference to use fly ash as a filler or reinforcement in metal and polymer matrices is that fly ash is a byproduct of coal combustion, available in very large quantities (80 million tons per year) at very low costs since much of this is currently land filled. Currently, the use of manufactured glass microspheres has limited applications due mainly to their high cost of production.

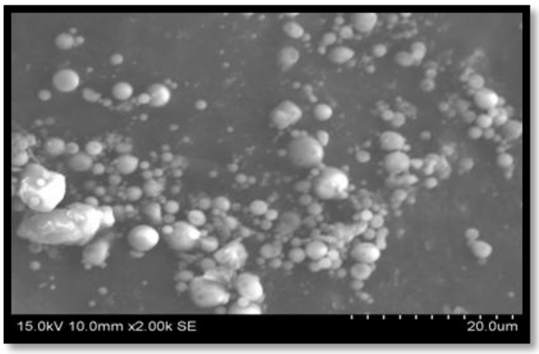

Fig 1 SEM of Fly Ash (2000x)

Therefore, the material costs of composites can be reduced significantly by incorporating fly ash into the matrices of polymers and metallic alloys. However, very little information is available on to aid in the design of composite materials, even though attempts have been made to incorporate fly ash in both polymer and metal matrices. Cenosphere fly ash has a lower density than talc and calcium carbonate, but slightly higher than hollow glass. The cost of cenosphere is likely to be much lower than hollow glass. Cenosphere may turn out to be one of the lowest cost fillers in terms of the cost per volume. The high electrical resistivity, low thermal conductivity and low density of fly-ash may be helpful for making a light weight insulating composites. Fly ash as a filler in Al casting reduces cost, decreases density and increase hardness, stiffness, wear and abrasion resistance. It also improves the machinability, damping capacity, coefficient of friction etc. which are needed in various industries like automotive etc.

II. EXPERIMENTAL PROCEDURE

A) SYNTHESIS

A stir casting set up which consisted of a resistance furnace and a stirrer assembly was used to synthesize the composite. The stirrer assembly consisted of a graphite turbine stirrer, which was connected to a variable speed direct current (D.C.) motor (speed 0 to 500 rpm) by means of a steel shaft. The stirrer was made by cutting and shaping a graphite block to desired shape and size. The stirrer consisted of three blades at angles of 120° apart. Clay graphite crucible of 1.5 Kg Al melt capacity was placed inside the furnace. Top pouring arrangement was made to cast the composite in metal mould. The stirrer assembly consisted of a graphite turbine stirrer fixed to a steel rod.

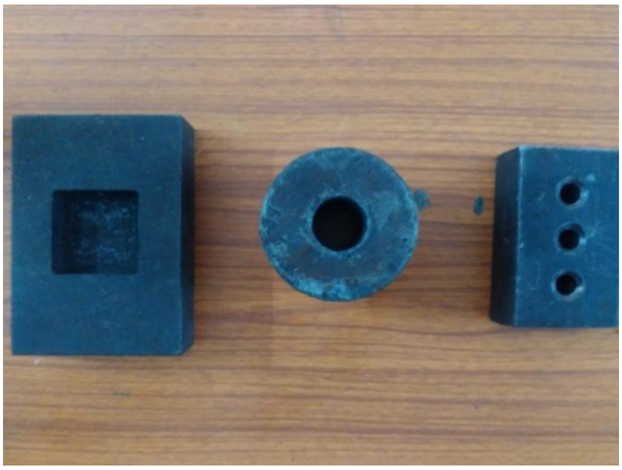

Fig. 2. Die Moulds

Fig.2 shows the photograph of the stirring the molten metal. Top pouring arrangement was made to cast the composite in metal mould. The stirrer assembly consisted of a graphite turbine stirrer fixed to a steel rod. Approximately 4200gms of alloy was then re-melted at 760°C in the resistance furnace of stir casting setup. The degassing hexa-chloroethane tablets were added to remove slag. Also 1.5% Mg is added to increase the wettability between matrix and reinforcements. Preheating fly ash and silicon carbide mixture at 450°C was done in a resistance furnace, placed near stir casting setup, to remove moisture and gases from the surface of the particulates. The stirrer was then lowered vertically up to 3 cm from the bottom of the crucible (total height of the melt was 9 cm). The speed of the stirrer was gradually raised to 400rpm and the preheated fly ash and silicon carbide was added with a spoon at the rate of 10-20g/min into the melt. The speed controller maintained a constant speed, as the stirrer speed got reduced by 50-60 rpm due to the increase in viscosity of the melt when particulates were added into the melt. The melt was kept in the crucible for one minute in static condition and it was then top poured in two small metal moulds successively. The stirring and pouring of molten metal is shown in Fig 5 & 6.

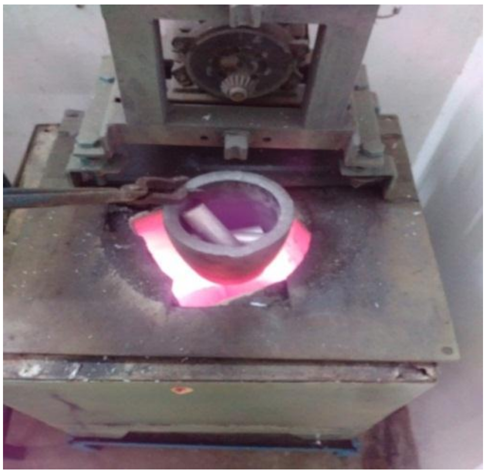

Fig. 3. Loading Al-alloy into the furnace

Fig.4. Weighing of Reinforcing Agents

Fig.5. Molten metal in crucible

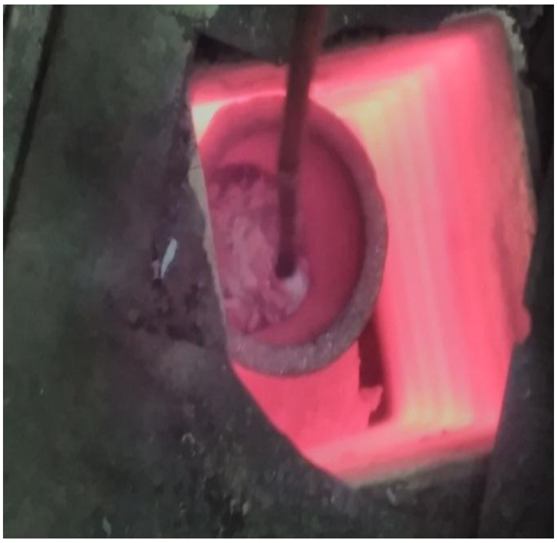

Fig. 6. Molten metal in the crucible with stirrer

Fig. 7.Pouring the molten metal into the mould cavity

Then the material was allowed to cool & solidify in the dies for 1-2 hours. After extraction from the dies, the materials in shape of rod were subjected to machining for removing any irregularities present on the surface. Then the material is subjected to heat treatment. The specimens are placed in an oven and kept there for 12-13 hours. The temperature maintained inside the oven was around 400-450 degrees. After keeping it for 12 hours, the specimens are taken out and quenching is done.

Table I.The composites combinations casted by stir casting

Sample No	Composite
Sample 1	Al-4.5%Cu alloy (As Cast)
Sample 2	Al-4.5%Cu+2%fly ash+2%SiC
Sample 3	Al-4.5%Cu+2%fly ash+4%SiC
Sample 4	Al-4.5%Cu+2%fly ash+6%SiC
Sample 5	Al-4.5%Cu+4%fly ash+2%SiC
Sample 6	Al-4.5%Cu+4%fly ash+4%SiC
Sample 7	Al-4.5%Cu+4%fly ash+6%SiC

The specimens are placed in water maintained at a temperature of 100 degrees. Heat treatment is a process usually done to alter the physical and sometimes chemical properties of a material. Metallic Materials consists of a microstructure of the small crystals called grains or crystallites.

III. RESULTS AND DISCUSSIONS

B. A) HARDNESS

Hardness measurements were performed using a Brinell hardness tester with a load of 10kgf shown in Fig 8. Hardness values were averaged over six measurements taken at different points on the cross-section. The table shows that incorporation of fly ash particles in Aluminum matrix causes reasonable increase in hardness. The strengthening of the composite can be due to dispersion strengthening as well as due to particle reinforcement. Thus, fly ash as filler in Al casting reduces cost, decreases density and increase hardness which are needed in various industries like automotive etc.

Table.II Hardness Results

Sample No.	Average Brinell Hardness Numbe
Sample 1	78
Sample 2	81
Sample 3	83
Sample 4	87
Sample 5	89
Sample 6	93
Sample 7	96

Fig.8. Hardness tested specimen

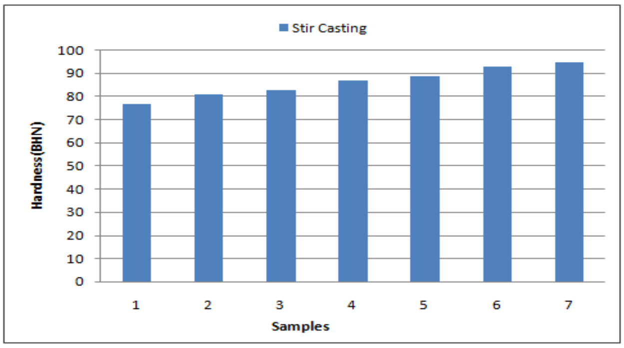

Fig.9.. Hardness of samples

The above table II shows that the incorporation of fly ash particles in Aluminum matrix causes reasonable increase in hardness. The strengthening of the composite can be due to dispersion strengthening as well as due to particle reinforcement. Thus, fly ash as filler in Al casting reduces cost, decreases density and increase hardness which are needed in various industries like automotive etc.It is clear from the bar chart that with the increase in composition of SiC& Fly ash, hardness of specimen increases.The maximum hardness identified is for Al-Cu alloy with 4% Fly ash and 6% SiC MMC.

B) COMPRESSION STRENGTH

Fig.10 shows the results obtained from uniaxial compression as a function of fly ash and SiC particulate. Increase in percentage of fly ash and SiC increases the compression strength of composites. This is due to the hardening of the base alloy by fly ash particulates. The SiC reinforcement has highest weight percentage and this may increase the density of the material which cause in increase in compressive strength.

Table.III Compression Strength Results

Sample No.	Ultimate Compression Strength (MPA)
Sample 1	551
Sample 2	612
Sample 3	632
Sample 4	654
Sample 5	701
Sample 6	720
Sample 7	735

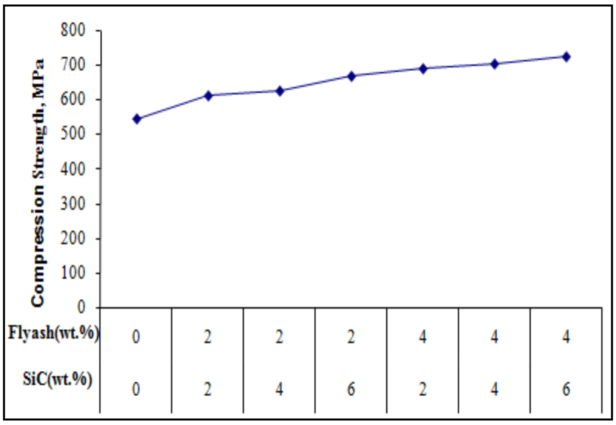

Fig.10. Compression strength of Al-4.5wt%Cu reinforced Fly ash and SiC particulates

C). IMPACT STRENGTH

From Fig.13. the impact strength also increases with increasing fly ash content. This may be due to the presence of hard fly ash and SiC particulates. The impact strength shows higher values for 4% fly ash, 6% SiC composites than the base alloy.

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Fig.11 Specimen after conducting Charpy Impact Test

Fig.12 Specimen after conducting Izod Impact Test

Table.IV Impact Strength Results

Sample No.	Impact Load (Izod), J	Impact Load (Charpy), J
Sample 1	2.5	2.1
Sample 2	2.8	2.5
Sample 3	3.5	3.1
Sample 4	4	3.6
Sample 5	4.9	4.3
Sample 6	5.5	4.8
Sample 7	6.2	5.6

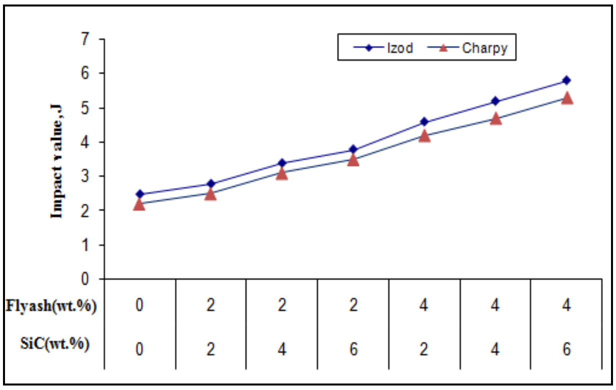

Fig.13. Impact strength of Al-4.5wt%Cu reinforced Fly ash and SiC particulate

D.) *WEAR BEHAVIOUR*

Wear behaviour of different composite was studied with different parameter like sliding velocity and applied loads. There result and discussion are given in the following subsections.

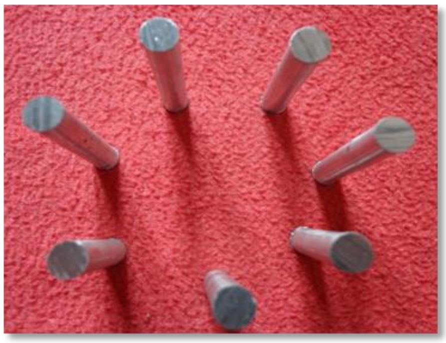

Fig.14. Specimen after Wear Test

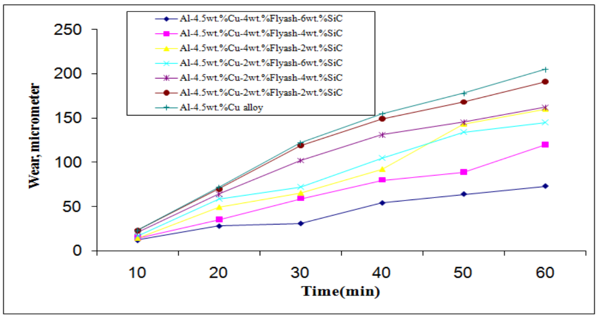

Fig.15. Wear vs. time at various percentage of fly ash and SiC at 10 N load of casting.

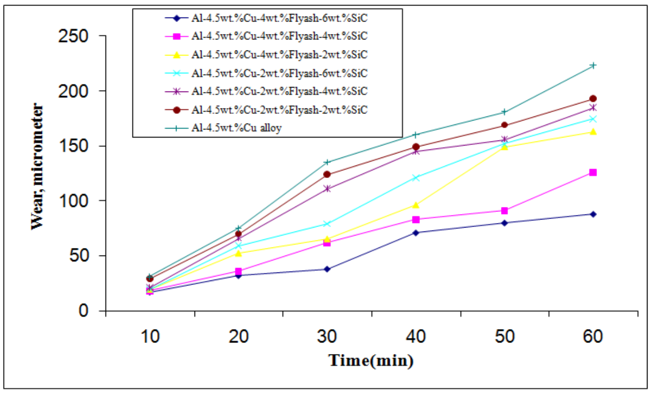

Fig.16. Wear vs. time at various percentage of fly ash and SiC at 15 N load of casting.

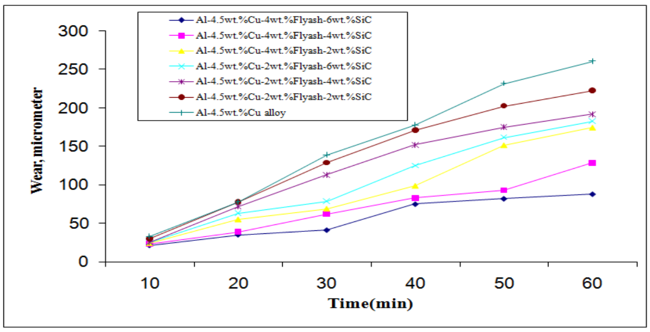

Fig.17. Wear vs. time at various percentage of fly ash and SiC at 20 N load of casting.

IV. CONCLUSION

The following conclusion may be drawn from the present work:

- From the study it is concluded that the reinforced composition of 4% Fly ash and 6% SiC shows better mechanical properties such as Hardness, Compression Strength, Impact Strength & Wear resistance, than that of unreinforced Al-Cu alloy.
- we can use fly ash for the production of composites and can turn industrial waste into industrial wealth. This can also solve the problem of storage and disposal of fly ash.
- Fly ash up-to 4% and SiC up to 6% by weight can be successfully added to commercially pure aluminum by stir casting route to produce composites.
- Hardness of commercially aluminium is increased from 78 BHN to 96 BHN with addition of fly ash and SiC.
- The Ultimate Compression strength has improved with increase in fly ash and SiC content. The Compression strength increased from 551MPa to 735MPa.
- The wear resistance of composites is much greater than the commercially pure aluminium.
- The effect of increased reinforcement on the wear behavior of the MMCs is to increase the wear resistance and reduce the coefficient of friction. The MMCs exhibited better wear resistance due to its superior load bearing capacity. Wear-resistance increases with increase in percentage of SiC and Fly ash.
- The Impact strength shows higher values for 4% fly ash, 6% SiC reinforced MMCs.

The SEM study reveals that there is uniform distribution of fly ash and SiC.

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