# A STUDY ON MECHANICAL PROPERTIES OF ALUMINIUM ALLOY (LM6) REINFORCED WITH SIC AND FLY ASH

[1]Vineeth Katkam,[2]Dr. Ashok Kumar Vangeri,[3] Deepak S. Patil, [4]Vaman Chavan, [5]Dipak R.Kale
[1, 3, 4,5]Research Schoolar,[2] Professor
[1-5]Mechanical Engineering,
[1]Shetty Institute of Technology, Kalaburgi, Karnataka, India

***Abstract:*** This work deals with fabricating or producing aluminium based metal matrix composite and then studying its microstructure and mechanical properties such as tensile strength, impact strength and wear behavior of produced test specimen. In the present study a modest attempt has been made to develop aluminium based MMCs with reinforcing material, with an objective to develop a conventional low cast method of producing MMCs and to obtain homogeneous dispersion of reinforced material. To achieve this objective stir casting technique has been adopted. Aluminium Alloy (LM6) and SiC, Fly Ash has been chosen as matrix and reinforcing material respectively. Experiment has been conducted by varying weight fraction of Fly Ash ( 5% and 15%) while keeping SiC constant(5%). The result shown that the increase in addition of Fly Ash increases the Tensile Strength, Impact Strength, Wear Resistance of the specimen and decreases the percentage of Elongation.

***Index Terms* - Fly Ash, Hybrid Composites, Silicon Carbide, stir casting.**

## I. INTRODUCTION

Aluminum is the most abundant metal and the third most abundant chemical element in the earth's crust, comprising over 8% of its weight. Aluminum alloys are broadly used as a main matrix element in Composite materials. Aluminum alloys for its light weight, has been in the net of researchers for enhancing the technology. The broad use of aluminum alloys is dictated by a very desirable combination of properties, combined with the ease with which they may be produced in a great variety of forms and shapes [1].

Discontinuously reinforced aluminium matrix composites are fast emerging as engineering materials and competing with common metals and alloys. They are gaining significant acceptance because of higher specific strength, specific modulus and good wear resistance as compared to ordinary unreinforced alloys. Reinforcing particles used in this study are silicon carbide and fly ash particles which are added externally [2].

Aluminium alloy (LM6) is used in Marine, Automobile, Aerospace industries. One of the main drawbacks of this material system is that they exhibit poor tribological properties. Hence the desire in the engineering community to develop a new material with greater wear resistance and better tribological properties, without much compromising on the strength to weight ratio led to the development of metal matrix composites [2].

Silicon carbide is a compound of silicon and carbon with a chemical formula SiC. Silicon carbide was originally produced by a high temperature electrochemical reaction of sand and carbon. Silicon carbide ceramics with little or no grain boundary impurities maintain their strength to very high temperatures, approaching 1600°C with no strength loss. It 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 [2].

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. Coal Combustion Products (CCP) is produced in coal-fired power stations, which burn either hard or brown coal. Due to the mineral component of coal and combustion technique, Fly Ash (FA) is produced. The utilization of fly ash instead of dumping it as a waste material can be both on economic and environmental grounds. There is already a vast body of information on utilization of Fly Ash (FA) in building/construction, production of aggregates and more recently for agriculture [2,6].

Composites are engineered or naturally occurring materials made from two or more constituent materials with significantly different physical or chemical properties that remain separate and distinct within the finished structure. The bulk material forms the continuous phase that is the matrix (e.g., metals, polymers) and the other acts as the discontinuous phase that is the reinforcements (e.g., ceramics, fibers, whiskers, particulates). While the reinforcing material usually carries the major amount of load, the matrix enables the load transfer by holding them together [3].

The challenges and opportunities of aluminium matrix composites have been reported much better to that of its unreinforced counterpart. The addition of reinforcing phase significantly improves the tribological properties of aluminium and its alloy system. The thinking behind the development of hybrid metal matrix composites is to combine the desirable properties of aluminium, silicon carbide and fly ash. Aluminium have useful properties such as high strength, ductility, high thermal and electrical conductivity but have low stiffness whereas silicon carbide and fly ash are stiffer and stronger and have excellent high temperature resistance but they are brittle in nature[2,5].

In this study an attempt has been made to fabricate a Hybrid Composite from commercial silicon carbide and fly ash. Aluminium alloy (LM6) is used as matrix material for the fabrication of LM6-SiC-fly ash hybrid composite material. Methods available for the production of Hybrid Composites are powder metallurgy, spray deposition, liquid metal infiltration, squeeze-casting, stir-casting. Though various processing techniques available for particulate or discontinuous reinforced metal matrix composites, stir casting is the technique, which is in use for large quantity commercial production. This technique is most suitable due to its simplicity, flexibility and ease of production for large sized components. Hence stir casting method is used in this study [4].

The objective of present work is to produce hybrid composites of LM6/SiC/fly ash by stir casting method. And determine the effect of addition of fly ash on mechanical and tribological properties of LM6-silicon carbide MMCs.

## II. MATERIALS AND METHOD

### 2.1 Materials

The materials used in this present investigation are LM6, SiC, Fly Ash. Here the grain size of the SiC(black) is 150µm and Fly Ash (brown) is 100µm. Chemical composition of LM6 and Fly Ash is given in Table 1 and Table 2.

### 2.2 Experimental Methodology

The synthesis of metal matrix composite used in the study was carried out by stir casting method. A stir casting setup, Consisted of a Induction Furnace and a stainless Steel stirrer assembly, was used to synthesize the composite. The stirrer assembly consisted of a stirrer, which was connected to a variable speed vertical motor of 400 rpm by means of a steel shaft. The stirrer was made by cutting and shaping a Stainless Steel block to desired shape and size manually. Graphite crucible of 1.5 Kg capacity was placed inside the furnace [4]. The graphical representation of stir casting was shown in Fig.1.

LM6 (Aluminium) was melted at 720°C in the Induction furnace. Preheating of reinforcement (Fly Ash at 350°C, silicon carbide at 350°C) was done for one hour 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 [4]. The speed of the stirrer was gradually raised to 400 rpm and the preheated reinforced particles were added into the melt. The speed controller maintained a constant speed of the stirrer, as the stirrer speed got reduced by 100 rpm due to the increase in viscosity of the melt when particulates were added into the melt. After the addition of reinforcement, stirring was continued for 4 to 6 minutes for proper mixing of prepared particles in the matrix. The melt was kept in the crucible for approximate half minute in static condition and then it was poured in the die [4]. The value of the Fly Ash varied by 5% & 15% keeping SiC constant by 5%. By this process three sets of specimens were prepared for each test.

## III. RESULT AND DISCUSSION

### 3.1 Microstructure Analysis

IV.

The morphology, density, type of reinforcing particles and its distribution have a major influence on the properties of particulate composites. The variables that govern the distribution of particles are solidification rate, fluidity, type of reinforcement and the method of incorporation. It is necessary to distribute particles uniformly throughout the casting during production of particulate composites. The first task is to get a uniform distribution of particles in the liquid melt and then to prevent segregation/agglomeration of particles during pouring and progress of solidification [2].

V.

The microstructures of the samples were observed to study the particle distribution. The casting procedure was examined under the Light optical microscope was used having 100X resolution to determine the reinforcement pattern and cast structure. A section was cut from the castings. They were grinded using emery paper. Before optical observation the samples were mechanically polished and etched by Keller‟s reagent to obtain better contrast. The optical micrographs of hybrid metal matrix composites are shown in Fig. As shown in the Fig.2, well-formed grain boundaries were observed after etching process. It is observed that particles were present more throughout the casting. The particle distribution strongly influences the physical and mechanical properties of the composites. The result shows that weight percentage of reinforcement increases with the addition of SiC and fly ash to the melt.

VI.

### 3.2Tensile Test

Tensile test is carried out at room temperature using universal testing machine. In this study it can be noted that the addition of SiC and Fly Ash particles improved the tensile strength of the composites. It is apparent that an increase in the volume fraction of Fly Ash particle results in an increase in the tensile strength [4]. Graph 1 and graph 2 shows the effect of the weight fraction on the tensile strength and percentage of elongation. The tensile strength of Sample 2(LM6+5%SiC+5%F.A.) is 182.64 N/mm2 and this value increases to a maximum of 238.26 N/mm2 for Sample3 (LM6+5%SiC+15%F.A.) which is about 30% improvement on that of Sample 2. Table 3 shows results of tensile test.

### 3.3 Impact Test (Charpy Test)

The Charpy impact test, 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 toughness [4]. Table 4 shows results of impact test.

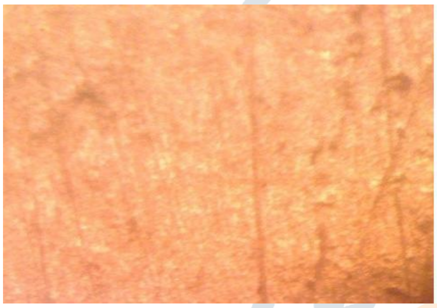
### 3.4 Wear Test

A cylindrical pin of size 8mm diameter and 24mm length Hybrid composite specimens were prepared and loaded in a pin- on-disc wear testing rig as shown in Fig.3. Before testing, the surface of the specimens was polished by using 1000 grit paper. Wear tests were carried out at room temperature for 5 and 10 minutes.

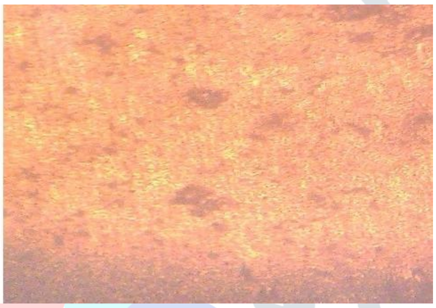
Wear, the progressive loss of material from the sliding surfaces of the elements of a tribo system can be determined in terms of weight loss. Material properties of the sliding elements, applied load and disc speed determine the wear rate. The result of wear test is shown in below Table 5 and Table 6. By these result we can see that the wear resistance is increased by increase in addition of fly ash in a LM6-SiC Hybrid composite. The result of weight loss is shown in below Table 7 and Table 8. The results of wear rate and wear resistance is tabulated in Table 9 and Table 10.

## IV. FIGURES AND TABLES

Fig.1 shows stir casting setup



(a) LM6



(b) LM6+5%SiC+5%F.A.

(c) LM6+5%SiC+15 F.A.%

Fig.2 shows the microstructure viewed by optical microscope for different weight fraction of Hybrid Composite

Fig.3 shows pin-on-disc wear testing machine

## V. RESULTS AND DISCUSSION

Table 1 Chemical composition of LM6.

| Components | Weight % |
|---|---|
| Copper | 0.09 |
| Magnesium | 0.06 |
| Silicon | 11.5 |
| Iron | 0.20 |
| Manganese | 0.30 |
| Zinc | 0.07 |
| Aluminium | Remainder |

Table 2 Chemical Composition of F.A.

| Components | Weight % |
|---|---|
| $SiO_2$ | 44.8 |
| $Al_2O_3$ | 22.2 |
| $Fe_2O_3$ | 24 |
| MgO | 0.9 |
| CaO | 1.8 |
| $TiO_2$ | 0.8 |
| $K_2O$ | 2.4 |
| $Na_2O$ | 0.9 |
| $SO_3$ | 1.4 |
| Balance = Oxides of other trace element | |

Table 3 Results of Tensile Test.

| Sample | Composition | Tensile Strength N/mm2 | Elongation (%) |
|---|---|---|---|
| Sample 1 | LM6 | 175.74 | 7 |
| Sample 2 | LM6+5%SiC+5%F.A. | 182.64 | 5 |
| Sample 3 | LM6+5%SiC+15%F.A. | 238.26 | 4 |

Table 4 Results of Impact Test

| Sample | Composition | Energy Absorbed kg-m |
|---|---|---|
| Sample 1 | LM6 | 6.8 |
| Sample 2 | LM6+5%SiC+5%F.A. | 7.5 |
| Sample 3 | LM6+5%SiC+15%F.A. | 8.5 |

Table 5 shows the result of weight loss by keeping Load 0.5kg, Time 5min.,& DiscSpeed300RPM

| Sample | Composition | Initial Weight in gm | Final Weight in gm | Weight Loss in gm |
|---|---|---|---|---|
| Sample 1 | LM6 | 96.1642 | 96.1452 | 0.0190 |
| Sample 2 | +5%SiC+5%F.A. | 96.2426 | 96.2312 | 0.0114 |
| Sample 3 | +5%SiC+15%F.A. | 96.0282 | 96.0196 | 0.0086 |

Table 6 shows the result of weight loss by keeping Load 1.5kg, Time 10min.,& Disc Speed 500RPM

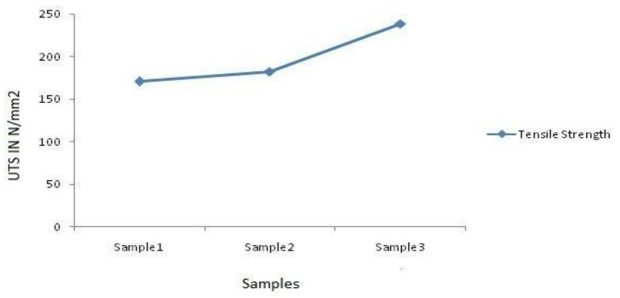
| Sample | Composition | Initial Weight in gm | Final Weight in gm | Weight Loss in gm |
|---|---|---|---|---|
| Sample 1 | LM6 | 96.1452 | 96.1196 | 0.0256 |
| Sample 2 | +5%SiC+5%F.A. | 96.2312 | 96.2168 | 0.0144 |
| Sample 3 | +5%SiC+15%F.A. | 96.0196 | 96.0092 | 0.0104 |

Table 7 shows the result of wear rate and wear resistance by keeping Load 0.5kg, Time 5min.,& Disc Speed 300RPM

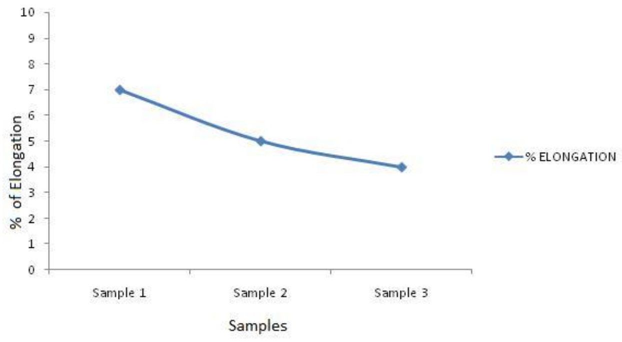
| Sample | Composition | Wear in µm | Wear Rate in mm3/m | Wear Resistance in m/mm3 |
|---|---|---|---|---|
| Sample 1 | LM6 | 162 | 0.024 | 41.66 |
| Sample 2 | +5%SiC+5%F.A. | 110 | 0.016 | 62.50 |
| Sample 3 | +5%SiC+15%F.A. | 82 | 0.012 | 83.33 |

Table 8 shows the result of wear rate and wear resistance by keeping Load 1.5kg, Time 10min.,& Disc Speed 500RPM

| Sample | Composition | Wear in µm | Wear Rate in mm3/m | Wear Resistance in m/mm3 |
|---|---|---|---|---|
| Sample 1 | LM6 | 186 | 8.50X10-3 | 117.64 |
| Sample 2 | +5%SiC+5%F.A. | 128 | 5.85X10-3 | 170.94 |
| Sample 3 | +5%SiC+15%F.A. | 94 | 4.29X10-3 | 233.10 |




**Graph 1** shows the effect of the weight fraction on the UTS




**Graph 2** shows the effect of the weight fraction on the % of Elongation.

## VI.CONCLUSION

a).LM6 based Hybrid composite up to 15% Fly Ash have been successfully fabricated by stir casting technique.

b).The microstructure study shows fairly uniform distribution of SiC and Fly Ash in LM6 based metal matrix composite.

c).It appears in this study that Tensile Strength starts increases with increase in weight percentage of Fly Ash. d).It found that elongation tends to decrease with increasing particles weight percentage which confirms that addition of SiC and Fly Ash increases the brittleness.

e).The impact strength of Hybrid composite increases with increase in weight percentage of Fly Ash.

f).It found that the wear resistance tends to increase with increase in addition of Fly Ash in LM6/SiC Hybrid composite.

g).From this study it is concluded that 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 of Fly.

## REFERENCES

**[1]** Basavaraju.S Arasukumar.K Dr.Chandrashekhar Bendigeri Dr.C.K.Umesh, Studies on Mechanical Properties and Tribological Characteristics of LM25- Graphite- Silicon Carbide and LM25-Flyash- Silicon Carbide - Hybrid MMC's, *International Journal of Innovative Research in Science, Engineering and Technology Vol. 1, Issue 1, November 2012.*

**[2]** Mahendra Boopathi, M., K.P. Arulshri and N. Iyandurai, Evaluation of Mechanical properties of Aluminium alloy 2024 reinforced with Silicon Carbide and Fly Ash hybrid metal matrix composites, *American Journal of Applied Sciences, 10 (3): 219-229, 2013.*

**[3]** Mr. Amol D. Sable1, Dr. S. D. Deshmukh, Preparation of metal matrix composites by stir casting method, *International Journal of Mechanical Engineering and Technology, Volume 3, Issue 3, September - December (2012), pp. 404-41.*

**[4]** Er. Sandeep Kumar Ravesh , Dr. T. K. Garg, Preparation & Analysis for some mechanical property of Aluminium based metal matrix composite reinforced with SiC & Fly Ash, *International Journal of Engineering Research and Applications, Vol. 2, Issue 6, November- December 2012, pp.727-731*

**[5]** Shanmughasundara, R. Subramanian and G. Prabhu, Some Studies on Aluminium – Fly Ash Composites Fabricated by Two Step Stir Casting Method, *European Journal of Scientific Research, ISSN 1450-216X Vol.63 No.2 (2011), pp.204-218.*

**[6]** H.C. Anilkumar , H.S. Hebbar and K.S. Ravishankar, Mechanical properties of Fly Ash reinforced Aluminium alloy(Al6061) composites, *International Journal of Mechanical and Materials Engineering (IJMME), Vol.6 (2017), No.1, 41 -45.*