

# Studies on Mechanical Properties and Tribological Characteristics of LM25- Graphite- Silicon Carbide and LM25-Flyash- Silicon Carbide - Hybrid MMC's

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**Abstract:** Hybrid MMC's have various advantages over conventional metals. Aluminum has a wide advantage in research field which is used as base metal in many MMC's. Aluminum LM25 is used as base metal in this work. The studies were done using graphite and flyash by varying the percentage of Silicon Carbide and aluminum LM25 as base metal. Graphite and flyash are added for 2 % of aluminium weight separately and Silicon carbide is varied for 2, 4, 6 and 8% weight of aluminium. The low density of Aluminum and hardness of Silicon carbide and graphite, and affinity of Flyash in Aluminum was to be evaluated as a hybrid structure. The mechanical properties such as tensile strength, Hardness and wear rate were increased after alloying with Graphite and Silicon carbide up to certain percentage. The primary advantage of the hybrid composite is the low density that is obtained after alloying. AlSiCFA is a lightweight material with a density one third of that of Cu alloys. The 2% SiC and 2% Graphite is the best combination of reinforcements that could be integrated in aluminum for best results. The hardness of the material increases with the combination of 2% addition of SiC and Graphite. The Silicon Carbide and Fly ash addition increases the tensile strength, hardness and wear resistance, but only up to a particular composition. The 2% SiC and 2% Fly ash is the best combination of reinforcements that could be integrated in aluminum for best results. The highest wear rate was measured in 8% SiC. Here the hardness of the alloy makes it unable to bear the wear. The AlSiCG and AlSiCFA hybrid composite materials preparation was cost effective and provides high performance related properties after testing for their mechanical behavior. The MMC's were tested for the evaluation of composite materials ability to replace existing advantages of aluminium LM25. Also to evaluate the hybrid reinforcement property of composites for their better usage.

**Keywords:** Aluminum LM25, Fly ash, Hybrid MMC's, Silicon Carbide, Stir casting, Tribological behavior.

## 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.

An attempt is made in this work where Aluminum LM25 is chosen as a matrix and reinforcements like Silicon Carbide (1200mesh size), Graphite (800 mesh size) and Flyash (800 mesh size) are mixed in proper proportions. Such multiple high performance reinforcements introduced into Aluminum alloy tend to be a Hybrid Composites. The Hybrid composite is estimated prepared, as conventional materials lack some qualities. To meet the ever-increasing engineering demands of modern technology, metal matrix composites are gaining importance. The basic idea is to obtain a hybrid composite by stir casting method by mixing Aluminum LM25, Graphite, fly ash and Silicon carbide in varying proportions. The Tensile, compression, Hardness, wear tests were performed and evaluated.

Aluminum LM25 has major composition of Silicon of 6.5%, and 0.2% Mg, Cu 0.1% and 0.3% Mn. Silicon Carbide is used for its major advantages such as low density, high strength, high thermal conductivity, and high elastic modulus. Fly ash is

a byproduct of Thermal Power Plant. Fly ash used in this project was from Rayalaseema Thermal Power Plant, Andhra Pradesh, India. 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 at very low costs since much of this is currently land filled. Therefore, the material costs of composites can be reduced significantly by incorporating fly ash into the matrices of polymers and metallic alloys. The thermodynamic analysis indicates that there is possibility between the reaction of Al melt and the fly ash particles. The particles contain alumina, silica and iron oxide which during solidification process of Al-fly ash composites or during holding such composites at temperature above 850<sup>0</sup> C, are likely to undergo chemical reactions.

This paper is organised as follows: Section I give the introduction of the work carried out. Section II give a note on experimental work and testing methods used. Section III gives a brief outlay on results and the same is compared and tabulated. The last sectionIV concludes the paper followed by references.

## II. EXPERIMENTS

Aluminum LM25 ingot was weighed and melted in electric furnace up to 800°C, and the 2% Graphite (2% of aluminium weight) was mixed using a mechanical stirrer for uniform dispersion. The Silicon carbide was added for 2, 4, 6, and 8 % weight of aluminum. The same method was prepared for 2% Fly ash and Silicon carbide in varying proportions as 2, 4, 6, and 8 %. The cast was poured into the mould and the specimens were machined according to ASTM standards required for testing. Tensile, compression, hardness and wear tests were conducted and the results were derived.

During melting Aluminum start dissolving the atmosphere gases in particular hydrogen. If these gases are not removed the casting formed will not be good. These gases are removed by adding Hexachloroethane pallets into the molten metal. Chlorine gas is liberated along with the other gases. By this degassing of the molten metal is done. Role of the degasser is to combine with hydrogen in solution in the molten metal, and to drive it out of the melt.

A mechanical stirrer with a refractory layer of coating was then introduced into the melt; the stirrer speed is 500 to 800rpm. When a satisfactory vortex was formed, pre-weighed reinforcements were added according to the required compositions and stirred for ten minutes and then pouring is done. The liquid metal was poured into the cast iron permanent moulds. The dies were allowed for cooling and then removed. Later the specimens were removed and were used to different testing.

The cast has to be poured into the mould, and therefore the mould has to withstand the temperature of the cast and give the shape to the liquid cast. For Aluminum casts the mould is prepared from Cast Iron, as its melting temperature is very high at 1600<sup>0</sup>C. The specimens were casted of sizes 25mm diameter and length of 450mm using a cast iron mould pattern. The specimens were machined for the shapes required to test Tensile strength, compressive strength, and hardness value and wear characteristics according to ASTM standards.

The density of a material plays an important role in MMC's. It is estimated by the Rule of Mixtures. Rule of Mixtures is a method of approach to approximate estimation of composite material properties, based on an assumption that a composite property is the volume weighed average of the phases (matrix and dispersed phase) properties. According to Rule of Mixtures density of composite materials is estimated by the following rule:

$$dc = dm*Vm + df1*Vf1 + df2*Vf2 \dots\dots\dots(1)$$

Where,

- dc – Density of the composite,
- dm - Density of the matrix, Aluminium
- Vm, – Volume fraction of the matrix.
- df1 – Density of reinforcement 1 (Graphite or Flyash)
- df2 – Density of reinforcement 2 (Silicon Carbide)
- Vf1 – Volume fraction of the reinforcement 1(2%)
- Vf2 – Volume fraction of the reinforcement 2 (2-8%)

## III.RESULTS AND DISCUSSIONS

### A.Density Comparision

The comparisons of densities by rule of mixture theoretically and experimentally for two compositions are shown in Table I for AlGSiC and Table II for AlFASiC.

**TABLE I**  
**Density comparison for AIGSiC MMC**

Sl No	Composition	Theoretical Density	Experimental Density
1	Al+2%G + 2% SiC	2.702	2.667
2	Al+2%G + 4% SiC	2.764	2.762
3	Al+2%G + 6% SiC	2.826	2.695
4	Al+2%G + 8% SiC	2.888	2.691

**TABLE II**  
**Density comparison for AIFASiC MMC**

Sl No	Composition	Theoretical Density	Experimental Density
1	Al+2%FA + 2% SiC	2.708	2.702
2	Al+2%FA + 4% SiC	2.864	2.792
3	Al+2%FA + 6% SiC	2.826	2.755
4	Al+2%FA + 8% SiC	2.888	2.791

The castings taken were weighed and the density was calculated by knowing the volume. The densities compared in Table I and Table II shows that the density of composites cast is almost relevant to the theoretical densities.

**B. Tensile strength test**

The Tensile strength of the composite is obtained using the Universal Testing Machine. The tensile strength obtained for different compositions are shown in Table III for AIGSiC and Table IV for AIFASiC.

**TABLE III**  
**Tensile strength of AIGSiC MMC**

Sl No	Composition	Tensile strength MPa
1	Al LM25	144
2	Al+2%G + 2% SiC	153
3	Al+2%G + 4% SiC	151
4	Al+2%G + 6% SiC	139
5	Al+2%G + 8% SiC	126

**TABLE IV**  
**Tensile strength of AIFASiC MMC**

Sl No	Composition	Tensile strength MPa
1	Al LM25	144
2	Al+2%FA + 2% SiC	146
3	Al+2%FA + 4% SiC	139
4	Al+2%FA + 6% SiC	111
5	Al+2%FA + 8% SiC	85

Table III indicates that the SiC addition leads to improvement in the ultimate tensile strength up to 2% only. Also, from the table it is clear that addition of SiC improves the tensile properties of the composite up to specific percentage.

The Tensile strength of the composite is more, thus strengthening the composite. This strength is due to dispersion strengthening as well as due to particle reinforcement. Dispersion strengthening is due to the incorporation of very fine particles, which help to restrict the movement of dislocations, whereas in particle strengthening, load sharing is the mechanism.

Also, the strength of the material considerably reduces in increasing % age of SiC more than 2%. The graphite inclusion also tends to define the properties of material. The material tends to be brittle after the fracture. Therefore, further addition of SiC reduces the strength.

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Also, the strength of the material considerably reduces in increasing % age of SiC more than 2%. The Fly ash inclusion also tends to define the properties of material. The material tends to be brittle after the fracture. Therefore, further addition of SiC reduces the strength.

**C. Compression test**

The compression test is conducted on a Universal Testing Machine and the results are tabulated in Table V for AIGSiC and VI AIFASiC. It is observed that the 2,4,6% of SiC is the best combination for obtaining the best combination of MMC. The mixture gives maximum compressive force that could be withstood by the material. Here the 2 ,4 and 6 % of SiC gives optimum selection.

TABLE V  
Max compression strength of AlGSiC MMC

Sl No	Composition	Max Compr strength kN
1	Al LM25	193
2	Al+2%G + 2% SiC	204
3	Al+2%G + 4% SiC	212
4	Al+2%G + 6% SiC	194
5	Al+2%G + 8% SiC	176

TABLE VI  
Max compressive strength of AlFASiC MMC

Sl No	Composition	Tensile strength MPa
1	Al LM25	193
2	Al+2%FA + 2% SiC	183
3	Al+2%FA + 4% SiC	188
4	Al+2%FA + 6% SiC	177
5	Al+2%FA + 8% SiC	155

#### D. Hardness test

The hardness test is conducted on a Brinells hardness testing equipment for a load of 500 Kg. The results thus obtained are tabulated in Table VII and VIII for AlGSiC and AlFASiC respectively.

TABLE VII  
Brinells hardness of AlGSiC MMC

Sl No	Composition	BHN
1	Al LM25	58.42
2	Al+2%G + 2% SiC	62.44
3	Al+2%G + 4% SiC	63.56
4	Al+2%G + 6% SiC	61.43
5	Al+2%G + 8% SiC	59.36

TABLE VIII  
Tensile strength of AlFASiC MMC

Sl No	Composition	BHN
1	Al LM25	58.42
2	Al+2%FA + 2% SiC	67.05
3	Al+2%FA + 4% SiC	70.09
4	Al+2%FA + 6% SiC	65.42
5	Al+2%FA + 8% SiC	64.23

The Table VII and VIII shows for the combination of AlGSiC the hardness increases till 4% of SiC and decreases increasing SiC. Also, in AlFASiC combination, the hardness increases till 4 % and decreases gradually after increasing to 8% of SiC. This shows the limitation of addition of SiC in varying Hardness property.

#### E. Wear test

Specimens are machined according to the ASTM standards and Wear characteristics of the MMC's are obtained by testing material on pin on disc apparatus. Varying load from 10N to 70N with rpm of disc at 100rpm, wear rate is recorded. The characteristics are determined by the comparison of the alloys for varying percentages of SiC along with Aluminium LM 25 alone is represented in Fig 1.

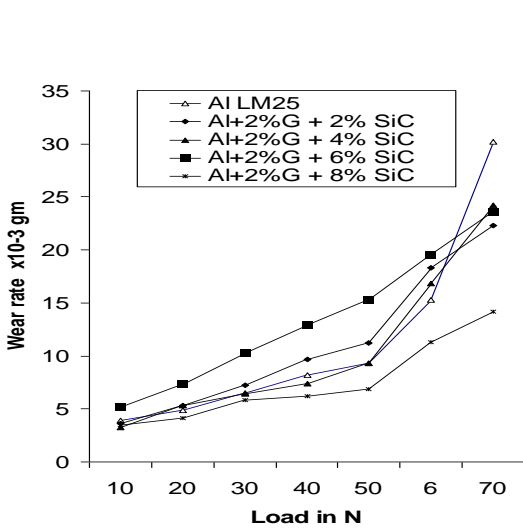


Fig.1. Wear Characteristics of AlGSiC MMC

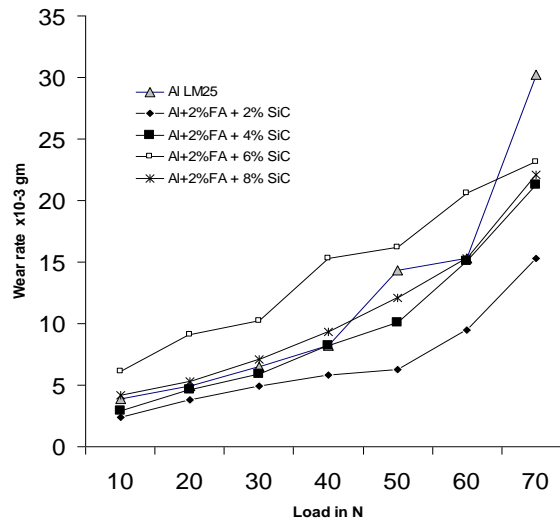


Fig.2. Wear Characteristics of AlFASiC MMC

The wear characteristics of all the compositions of AlGSiC are plotted above in Fig. 2. The highest wear rate is measured in 8% SiC composition that gives the material a brittle structure. The best wear performance out of the above compositions is obeyed by the 2% Graphite and 2% SiC. This shows that the wear resistance is offered less the correct combinations of the graphite and silicon carbide.

It is observed from the Fig.2. that the wear arte of the compositions AlFASiC measured on pin on disc apparatus, the most efficient and proportional mixing of up to 4% SiC and 2% Fly Ash gives good results with wear resistance. Therefore, addition of SiC into Al LM25 tends the material to loose its property and wear characteristics to reduce with higher percentage.

#### IV. CONCLUSION

The production and evaluation of tribological properties of AlGSiC and AlFASiC were done according to the standards. From the study it is shown that the Graphite and Silicon Carbide can be used for the production of composites and can provide good results for many applications. Flyash can be used for preparing MMC's which can turn industrial waste into industrial wealth. This can also solve the problem of storage and disposal of fly ash. Graphite and Fly ash mixed with SiC makes the material harder up to a certain limit. Prepared MMC's provide excellent wear characteristics up to a limit load. The tensile strength improves for 2% addition of SiC and 4% of SiC in Al+Graphite. This proportion is ideal for many results to outcome easily. Similarly, 2% and 4% addition of SiC in Flyash combination makes a efficient material. The hardness of the material increases with the combination of 2% addition of SiC and Graphite. The compressive strength is ideal at 2% and 4% addition of SiC graphite and Flyash.

The 2% SiC and 2% Graphite is the best possible mixture for ideal usage of aluminium. The material tends to wear up to addition of 4% of SiC rapidly. Lower the load applied higher the wear for 2% to 8% addition of SiC. Therefore the characteristics of phase constituents play important role on these alloys. The highest wear rate is measured in 8% SiC. Here the hardness of the alloy makes it unable to bear the wear.

Comparing the density and cost of the alloys suggests that the alloys containing 2% and 4% SiC would be cost effective and energy efficient for wear and strength applications.

Further scope is required in these combinations which can be of great application that would work out for various applications. Many applications like wear resistant Aluminum alloy for automobile engine casing and in household utensils.

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