Investigation of Mechanical Properties and Wear Behavior of Lm 25 Aluminum Alloy Reinforced With Silicon Carbide and Activated Carbon

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Abstract **– Today the MMC's have find wide applications in all the engineering fields due to their light weight and high strength parameters, especially in the field of automobile and mechanical industries The aluminium MMC have got wide applications due to their excellent mechanical properties. In automobile industries the LM 25 aluminium is used in manufacturing of alloy wheels, connecting rod, engine blocks, and engine heads etc. In LM25 if they are reinforced with Silicon carbide and Activated Carbon, their total weight can be reduced and mechanical properties can be improved. In this sense we have selected the LM 25 Al alloy is used as a matrix material, Silicon carbide and Activated Carbon as reinforcements. The mechanical test results revealed that the LM 25 MMC's have excellent wear resistance. The composite has been produced by Liquid metallurgy technique (stir casting). The properties of chosen composite is compared with base metal for Tension, Compression, wear and Hardness. This paper is aimed at development of aluminium metal matrix composites with hybrid reinforcement. Here aluminium alloy (LM25) has been selected as base metal along with silicon carbide various weight ratio and 2% activated carbon (AC) have been taken as reinforcements to produce hybrid composite.**

Keywords: **Aluminium alloy LM25, Stir casting, Microstructure, Hardness, Wear**

I. INTRODUCTION

A new class of materials called 'Composite materials' has answered to this search to a great extent. Composite materials are created artificially by combining two or more materials which usually have dissimilar characteristics. The constituents of a composite material can be generally identified macroscopically. This is in contrast to usual metallic alloys whose phases can be identified only under higher magnification or microscopic examination. Composite materials are new generation materials produced to meet the demands of automobile and aircraft industries. Any experimental technique involves design of experiment, method of measurement of various properties, documentation, testing, analysis and reporting. Production of Metal Matrix Composites (MMC) involve various steps such as melting using a furnace, melt treatment, introducing the reinforcement, casting, preparation of samples for various tests and testing the casting, preparation of samples for various tests and testing the specimen. By taking up this paper our endeavor is to understand the process of manufacturing MMC's, their testing, analysis and comparison with other material.

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Satyanarayen, Dominic Roystan, and Shreesaravanan studied the tensile test, hardness and microstructure of LM 25 and silicon composites by using stir casting method [1], R. M. Arunachalam , R. Sasikumar and S m suresh and team their research shown about hardness, strength and microstructure of Nano Al2O3 particle reinforced with LM 25. Aluminium composites[2], Mohammd Farooq and B motgi studied on the microstructure and tribological behavior of LM 25 ,silicon and mica hybrid composites [3],Anoop agarwal,Harwind singh and Gurdyal singh studied about Fly ash based aluminium omposites[4],Kumarvel,Venkatachalan and Arunkumar studied the microstructure of modified Lm 25 Al alloy [5], Eddy S.Siradj, Bambang Suharno, Bondan T. Sofyan and team developed steel wire rope reinforcement in aluminium composites in armour material using squeeze Casting Process[6]. The LM 25 aluminum alloy actually used where high strength is required .it has resistance to corrosion is the main advantage, better weldability and has got wide applications like in automobiles, food ,marine, and in transport where it is used as a alloy wheels, wheel rims, engine blocks, engine heads and other engine body parts. It has got very good casting and moulding characteristics. After reinforcement i.e LM 25 aluminum alloy with silicon carbide

and activated carbon. The combinations of these two materials is a resulting AMMC (Aluminium metal matrix composite)where reinforced silicon carbide and activated carbon becomes a integral part of LM25 and responsible to take higher loads which results in improved mechanical properties like improved impact strength and microstructure study shows good bonding between matrix and reinforcement. To get accurate results the casting and moulding should be done with good care and components should be free from impurities and blow holes and specimens are prepared as per ASTM standards and mechanical tests are conducted to know the strength of the composites.

II. EXPERIMENTAL DETAILS

2.1 MATERIALS

In the present investigation, Aluminium alloy LM25, in the form of ingots was used as base matrix material. The various percentage of Silicon Carbide and activated carbon in the form of particles were used as the reinforcing material. 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. The primary raw material used for activated carbon is any organic material with a high carbon content (coal, wood, peat, coconut shells). Granular Activated Carbon Media is most commonly produced by grinding the raw material, adding a suitable binder to give it hardness, re-compacting and crushing to the correct size. The carbon-based material is converted to activated carbon by thermal decomposition in a furnace using a controlled atmosphere and heat. The resultant product has an incredibly large surface area per unit volume, and a network of submicroscopic pores where adsorption takes place.

Table 1 shows the chemical composition of Aluminium alloy LM 25.

Si	Fe	Cu	Mn	Mg	Zn	Al
7.2%	0.5%	0.2%	0.3%	0.60%	0.1%	balance

2.2 FABRICATION OF COMPOSITES:

To prepare a composite material, liquid metallurgy technique, stir casting process was used. Since stir casting process is economical, mass production and the required size and shape of composite can be produced. Stir casting process is as shown figure and has been adopted in order to produce adequate homogeneous particle distribution throughout the matrix material. The crucible with the alloy was kept inside a 3phase Resistance furnace and mines were switched on. The alloy ingot will melt slowly. The temperature of the melt inside the furnace was noted ion the temperature recorder. The temperature was checked with an alumel-chromel thermocouple before the crucible out of the furnace. The crucible as shown figure 1 was taken out of the furnace in the melt temperature was around 850°C.

The aluminum alloy was melted in an electrical furnace. The stirrer was introduced to perform mixing process when the molten temperature reached 8500C. The stirring was carried out for 45 minutes at the rate of 200 rpm. Silicon carbide and Activated Carbon particles were preheated to 200 0C and introduced into the molten alloy. The pouring temperature of molten mixture was 8500C and molten metal was poured into the die. The molten metal was degassed using hexa-chloroethane (C2CL6) tablets as degassing agent (0.5% weight of metal). The degassing method as shown in figure 2, in which tablet was plunged into the metal and held at the bottom to enable chlorine gas to purge through the melt and remove dissolved gasses. Then the MMC was ejected from the die at a temperature of 150oC and it is allowed to cool in air.

Fig. 1 Crucible inside the furnace

Fig. 2 Degassing

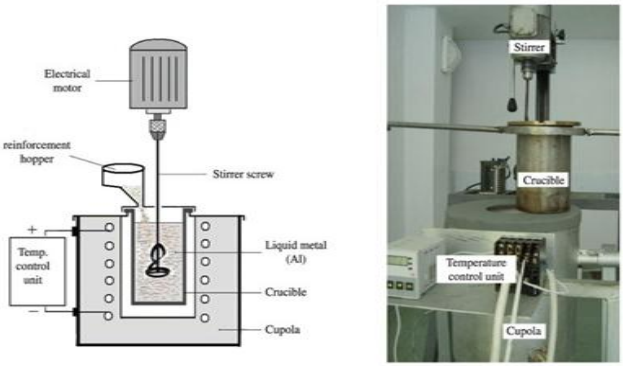

Fig. 3 Stir casting set-up

The composites were fabricated with different weight percentage of reinforcement viz 2%, 4% and 6% of silicon carbide particles.

2.3 EXPERIMENTAL WORK

A. Tensile Test:

Tension test is carried out; to obtain the stress-strain diagram, to determine the tensile properties and hence to get valuable information about the mechanical behavior and the engineering performance of the material. The Tensile test was conducted on Al 7075 hybrid composite specimens prepared as per ASTM E-8 standard using a computerized Universal Testing Machine.

Fig. 4 Tensile Test Specimens

B. Hardness Test:

Hardness is the property of a material that enables it to resist plastic deformation, usually by penetration. However, the term hardness may also refer to resistance to bending, scratching, abrasion or cutting. Macroscopic hardness is generally characterized by strong intermolecular bonds. There are three types of tests used with accuracy by the metals industry; they are the Brinell hardness test, the Rockwell hardness test, and the Vickers hardness test. But in our present work we considered only Brinell hardness test. The Brinell hardness test method as used to determine Brinell hardness, is defined in ASTM E10. The Brinell method applies a predetermined test load (F) to a carbide ball of fixed diameter (D) which is held for a predetermined time period and then removed. The resulting impression is measured across at least two diameters – usually at right angles to each other and these result averaged (d). A chart is then used to convert the averaged diameter measurement to a Brinell hardness number. Test forces range from 500 to 3000 kgf.

Fig. 5 Hardness Test Specimens

Fig. 6 Brinell Hardness Number-Tester

C. Dry Sliding Wear Test:

Dry sliding wear test was carried out using Ducom (Pin-on-disc) wear and friction test apparatus as per ASTM G99-95 standards under 5kg load and varying sliding speed. The Pin-on Disc machine, consisted of a steel disc that was carried by a mandrel driven by a motor. The test specimens consisted of two cylindrical pins that were mounted on a hydraulic loading mechanism consisting of dead weights, spindle and hydraulic cylinder. The pins, which were coaxial among themselves, contacted the disc from both sides vertically below the axis of the disc and at a track radius of 80 mm. The tangential force resulting from the friction between the pins and the disc was measured by means of a force transducer. The signal from the force transducer was continuously recorded.

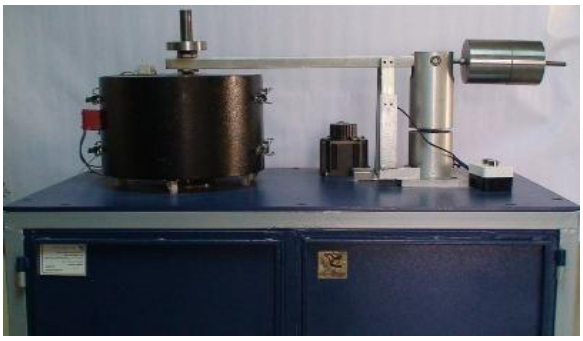

Fig. 7 Pin-On-Disc Wear Testing Machine

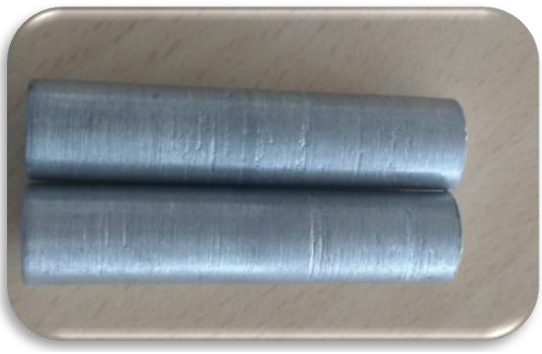

Fig. 8 Wear Testing Specimens

D. Density:

The density is the physical property of the material. The density of the material can be defined has mass per unit volume. The density is basically conducted to know how compactly matter is together crammed. The Archimedes is a Greek scientist who invented the principle of density. Mathematically the density can be represented as follows. Density can be useful in identifying substances. It is also a convenient property because it provides a link (or conversion factor) between the mass and the volume of a substance. Density plays a most vital role in the composite materials study. As these materials having greater importance and scope in aviation, automotive industry and many more applications where weight is vital parameter taken into account. Hence they must be of light weight, so the density of the composite should be reduced by adding certain reinforcement materials like Silicon carbide and Activated Carbon

Density Test Theoretically:

$\rho = \frac{m}{v}$, Where, ρ= density in g/cm3

m= mass in g

v=volume in cm^3

Density Test Experimentally:

The weight of the sample is measured in air. The sample is immersed in water and the weight of the sample is measured. The density of the material is calculated using formula

$$\rho = \frac{\text{weight of sample in air}}{\text{weight of sample in air} - \text{weight of sample in water}}$$

III. RESULTS AND DISCUSSIONS:

3.1 Microstructure Studies:

In the present paper, used optical microscope to conduct the microscopic study of Al-LM25+6%SiC+2%AC, Al-LM25+4%SiC+2%AC and Al-LM25+2%SiC+2%AC.

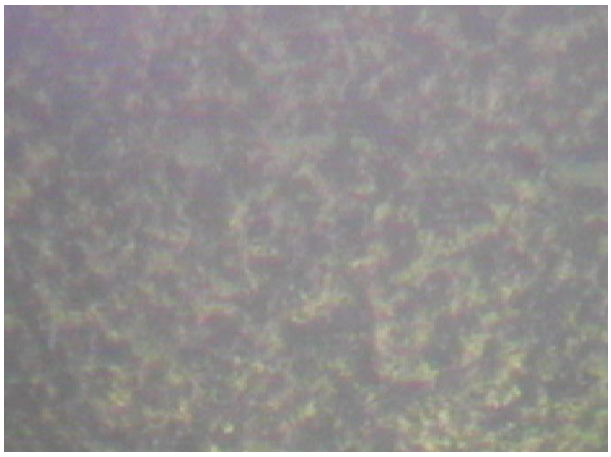

Fig. 9 Microstructure of Al-LM25+6%Sic+2%AC

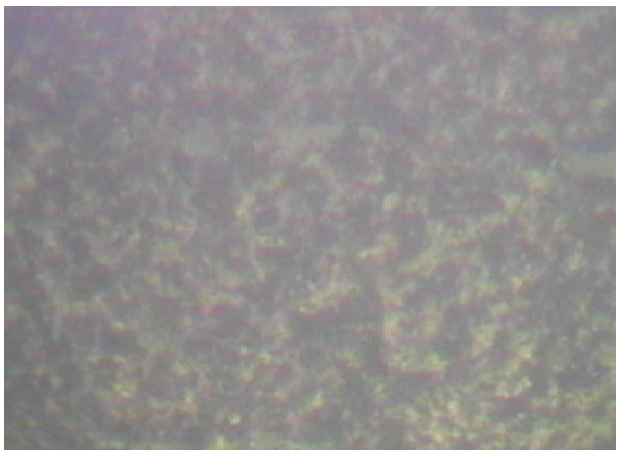

Fig. 10 Al-LM25+4%SiC+2%AC

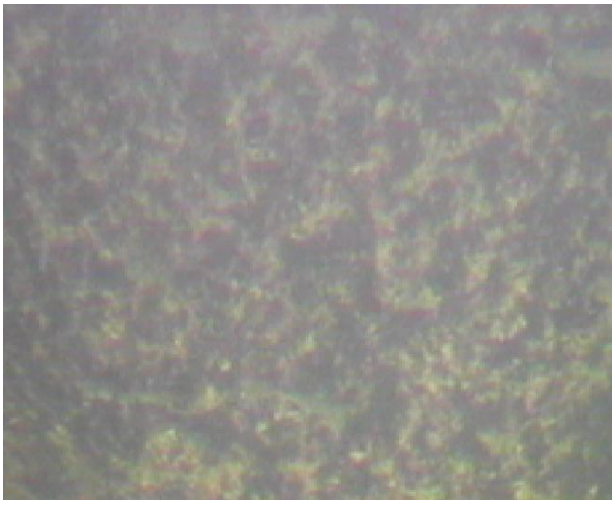

Fig. 11 Microstructure of Al-LM25+2%SiC+2%AC

It is clear from the Optical microscope images that there is homogeneity in the distribution of reinforcements (Silicon Carbide / Activated Carbon) in the matrix (LM 25) alloy, along with the evidence of minimal porosity in the composites. Also it is with excellent interface bonding exists between reinforcement and base matrix, where the reinforcements, (Silicon Carbide and Activated Carbon) are

surrounded by solid solution of LM 25.

Tensile and Hardness Test:

The tensile tests are conducted in UTM (MECH-002, UTE-60, 60T) having load capacity 600KN and also have an accuracy of ±1%. Specimens were prepared according to ASTM E-8M.

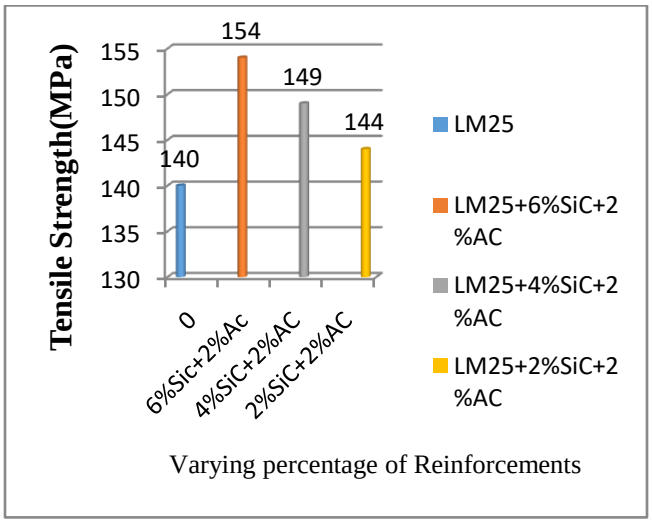

Fig. 12 Tensile strength Vs Varying percentage of reinforcements

From the above chart it is evident that for the combination of Al & 6%SiC+2%AC the Tensile Strength has increased, for the combination of Al & 2% SiC+2%AC the Tensile Strength has decreased, but above the strength of base material and for the combination of Al + 4%SiC + 2%AC the Tensile Strength is in between of Al & 6%SiC+2%AC and Al & 2% SiC+2%AC and still better than LM 25.

Tensile strength for the base metal is 140 MPa and maximum strength was found to be 154 MPa for Al & 2% SiC+2%AC.

Hardness:

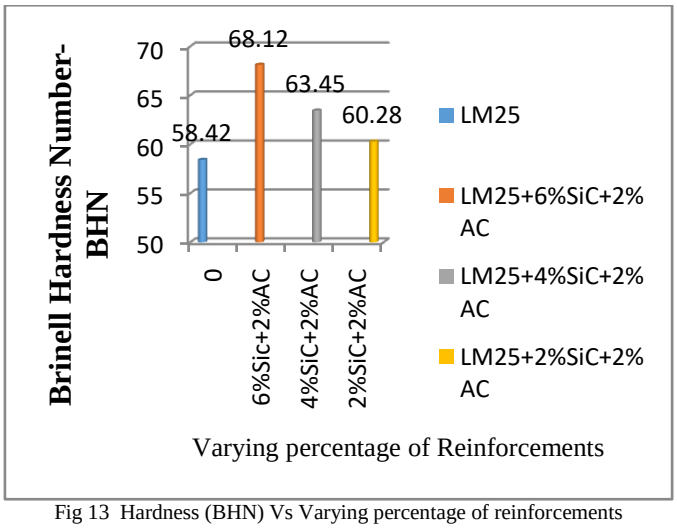

Fig 13 Hardness (BHN) Vs Varying percentage of reinforcements

From the above hardness results it is evident that for the combination of Al & 6%SiC+2%AC the Hardness has increased, for the combination of Al & 2% SiC+2%AC the hardness has decreased and for the combination of Al + 4%SiC + 2%AC the Hardness is in between of Al & 6%SiC+2%AC and Al & 2% SiC+2%AC and still better than LM25. The maximum BHN was found to be 68.12 for LM 25 + 6%SiC+2%AC.

Dry Sliding Wear and Frictional Force Studies:

The wear is the tribological property of the material. The wear test is conducted using a pin disc method. The wear rate and the frictional force are obtained from this method. Here the wear test was conducted for a constant load and time for varying speed conditions.

Wear test results for Al-LM25 + 6%SiC+2%AC

The below table shows the wear test results for a constant load and time for varying speed conditions for the specimen composition Al-LM25 + 6%SiC+2%AC.

Table 2 Wear test results for Al-LM25 + 6%SiC+2%AC

Specimen Composition	Speed in rpm	Load in kg	Time in min.	Wear rate in µm	Frictional force in N
Al-LM25 + 6%SiC+2%AC	400	5	10	314	8.15
	600	5	10	442	23.77
	800	5	10	536	25.68

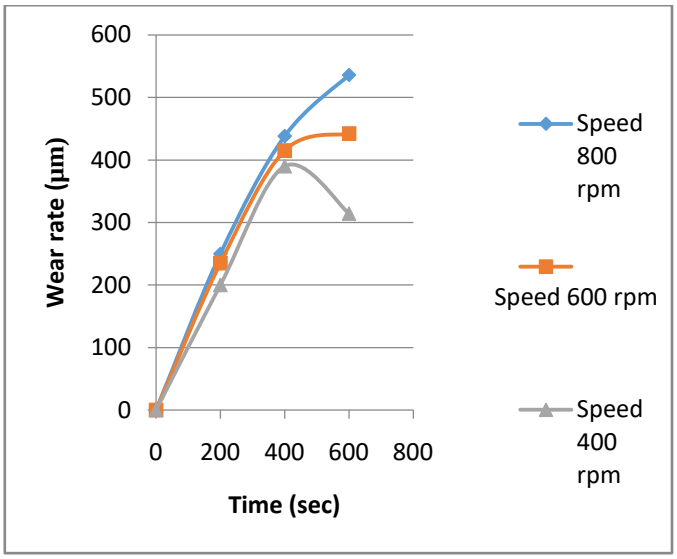

Fig. 14 Wear rate comparison for different speed

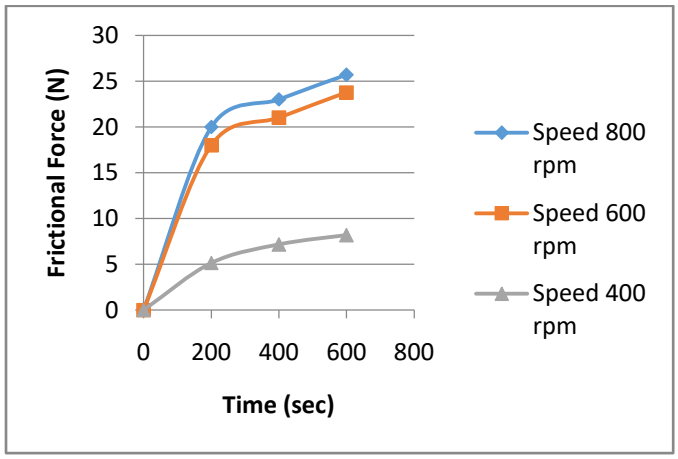

Fig. 15 Friction force comparison for different speed

From the above figure the wear rate and frictional force for different speeds for the combination of Al-LM25 + 6%SiC+2%AC. The above graph is plotted wear rate v/s time and frictional force v/s time. It is evident that for the combination of Al-LM25 + 6%SiC+2%AC the wear rate increases as the speed increases. The wear rate increases proportionally to the frictional force.

Wear test results for Al-LM25 + 4%SiC+2%AC

Table 3 Wear test results for Al-LM25 + 4%SiC+2%AC

Specimen Composition	Speed in rpm	Load in kg	Time in min.	Wear rate in µm	Frictional force in N
Al-LM25 + 4%SiC+2%AC	400	5	10	298	7.15
	600	5	10	364	20.45
	800	5	10	453	21.67

The above table shows the wear test results for a constant load and time for varying speed conditions for the specimen composition Al-LM25 + 4%SiC+2%AC

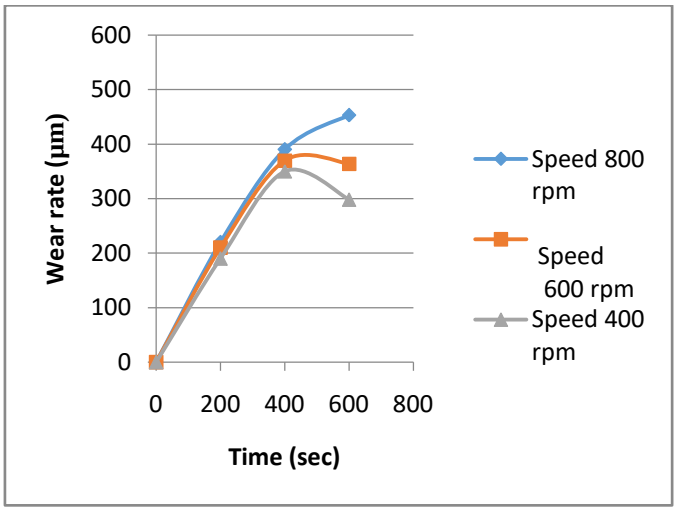

Fig. 16 Wear rate comparison for different speed

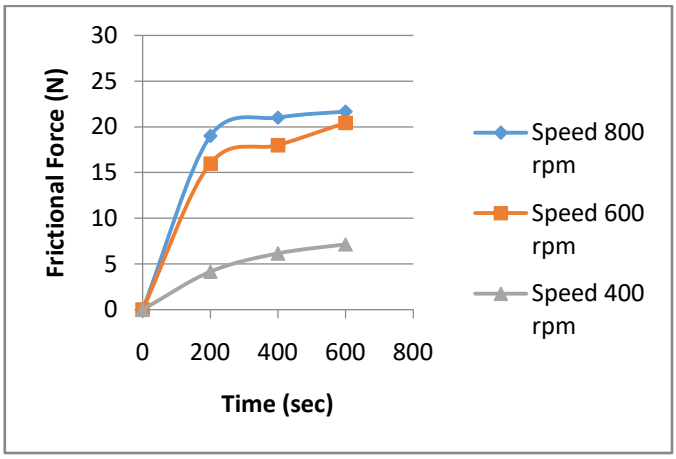

Fig. 17 Friction force comparison for different speed

From the above figure the wear rate and frictional force for different speeds for the combination of Al-LM25 + 4%SiC+2%AC. The above graph is plotted wear rate v/s time and frictional force v/s time. It is evident that for the combination of Al-LM25 + 4%SiC+2%AC the wear rate increases as the speed increases. The wear rate increases proportionally to the frictional force.

Wear test results for Al-LM25 + 2%SiC+2%AC

Table 4 Wear test results for Al-LM25 + 2%SiC+2%AC

Specimen Composition	Speed in rpm	Load in kg	Time in min.	Wear rate in µm	Frictional force in N
Al-LM25 + 2%SiC+2%AC	400	5	10	304	7.50
	600	5	10	413	21.78
	800	5	10	489	22.94

The above table shows the wear test results for a constant load and time for varying speed conditions for the specimen composition Al-LM25 + 2%SiC+2%AC.

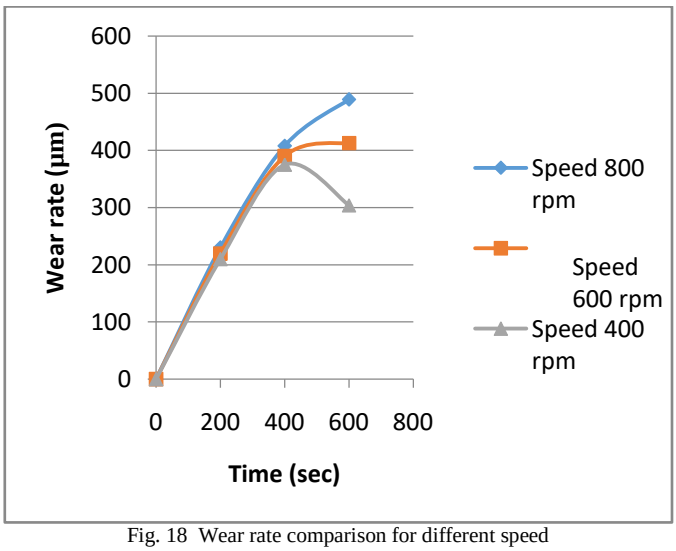

Fig. 18 Wear rate comparison for different speed

From the above and below figure the wear rate and frictional force for different speeds for the combination of Al-LM25 + 2%SiC+2%AC. The above graph is plotted wear rate v/s time and frictional force v/s time. It is evident that for the combination of Al-LM25 + 2%SiC+2%AC the wear rate increases as the speed increases. The wear rate increases proportionally to the frictional force.

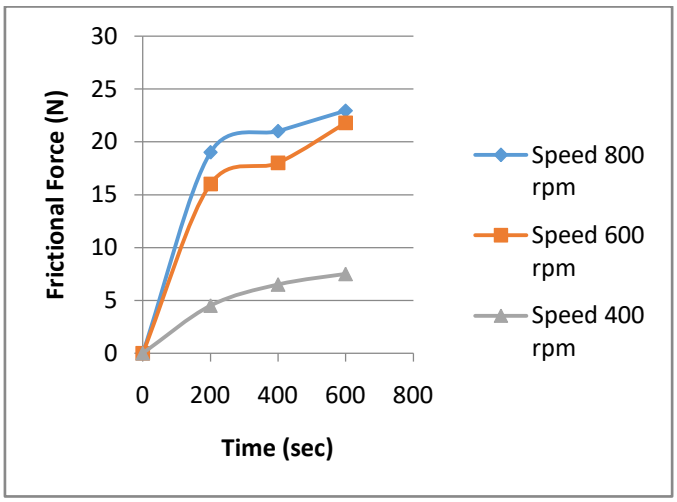

Fig. 19 Friction force comparison for different speed

Density Test Results:

Table 5 Density Test Results

Sl. No	Composition	Theoretical Density(g/cm^3)	Experimental Density(g/cm^3)
1	Al-LM25	2.68	2.6
2	Al-LM25 + 6%SiC+2%AC	2.721	2.701
3	Al-LM25 + 4%SiC+2%AC	2.705	2.70
4	Al-LM25 + 2%SiC+2%AC	2.695	2.689

The samples were weighed and the density was calculated by knowing the volume. The densities compared in table (5) shows that the density of metal matrix composites cast is almost relevant to the theoretical densities.

IV. CONCLUSIONS

The production and evaluation of properties of MMC's were done according to the standards. From the study it is seen that the Activated Carbon and Silicon Carbide can be used for the production of composites and can provide good results for many applications.

The following observations were made:

The tensile strength of the composite materials increases with increase in SiC reinforcements. Tensile strength for the base metal is 140 MPa and maximum strength was found to be 154 MPa for Al & 2% SiC+2%AC.

The hardness strength of the composite materials increases with increase in SiC reinforcements. Al & 6%SiC+2%AC the Hardness has increased, for the combination of Al & 2% SiC+2%AC the hardness has decreased and for the combination of Al + 4%SiC + 2%AC the Hardness is in between of Al & 6%SiC+2%AC and Al & 2% SiC+2%AC and still better than LM25. The maximum BHN was found to be 68.12 for 6%SiC+2%AC

The wear rate for the metal matrix composite increases with increase in speed for a given constant load and time.

The density of metal matrix composites cast is almost relevant to the theoretical densities.

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