STUDIES ON MECHANICAL PROPERTY, WEAR BEHAVIOUR AND MICROSTRUCTURE OF LM-25 AMMCs - A REVIEW

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Abstract:

The present study involves the investigations on the mechanical property, wear behaviour and micro structure of Aluminium LM-25 Composite. The various reinforcements considered for this study were SiC, graphite, fly ash and the matrix material is Aluminium LM-25. Many researchers found that the specimens were mostly prepared by Stir casting technique, though more number of processes has been used. Many experiments were conducted for analysing tensile property of composites and it was found that the tensile strength increases when the weight% of reinforcement is limited to 2%. Similarly, wear tests were conducted and it was concluded that wear rate increases with the increase in load. Finally, micro structure of Aluminium LM-25 Composite was examined by Scanning Electron Microscope (SEM).

Keywords:

Composites, Metal Matrix Composites (MMCs), Aluminium LM-25, Stir casting, Tensile strength, Wear behaviour, Micro structure.

1. INTRODUCTION

A composite material is one which composes of two or more constituent material which significantly consists of two phases, matrix phase and reinforcement phase. Such composite materials include metal composites ceramic composites, reinforced plastics, mortars, ceramics etc. The significance of composite materials are:

- Increase in yield and tensile strength at elevated temperatures
- Increase in creep resistance
- Increase in fatigue strength at higher temperatures
- Improvement of wear and tear, thermal shock, and corrosion resistance.[1-3]

MMC's are composed of two or more chemically non-reactive materials, with enriched mechanical properties such as ductility, hardenability, tensile, strength etc. and such materials include titanium, aluminium, magnesium and commonly used reinforcement materials are silicon carbide, fly ash or graphite, boron nitrite, etc., [4,5]. One such metal matrix composite used in many applications is aluminium. Thus aluminium metal matrix composites play a significant role in automotive industries especially due to its light weight. Apart from automotive industries it is widely used in aerospace, marine and other engineering applications. Aluminium metal matrix composites have excellent material characteristics such as

- light in weight
- good erosion resistance
- withstand high temperature
- very good recycling possibility

In this paper Aluminium LM-25 is chosen. Its mechanical properties, wear behaviour and micro structure of various reinforcements are studied and the results are discussed [6,7].

1.1 Aluminium Alloy LM-25

LM-25 is widely employed because of its excellent mechanical properties such as:

- excellent cast ability
- desired soundness
- resistance to corrosion
- good wet ability
- high strength
- high electrical and thermal conductivity

Aluminium LM-25, have greatly performing in many applications which includes food, marine, chemical, electrical industries, apart from these industries it significantly plays a vital role in automotive industry especially the parts includes cylinders, wheels and heads[8].

TABLE 1 CHEMICAL COMPOSITION OF ALUMINIUM LM-25 ALLOY

Element	**% by weight**
Copper	0.1
Magnesium	0.2-0.45
Silicon	6.5-7.5
Iron	0.5
Manganese	0.3
Nickel	0.1
Zinc	0.1
Lead	0.1
Tin	0.05
Titanium	0.2
Aluminium	remainder

2. EXPERIMENTAL PROCEDURE

There are various methods and processes by which AMMC can be fabricated, they are

- Stir casting
- Squeeze casting
- Powder metallurgy
- Infiltration process
- In situ casting process
- Compo casting process

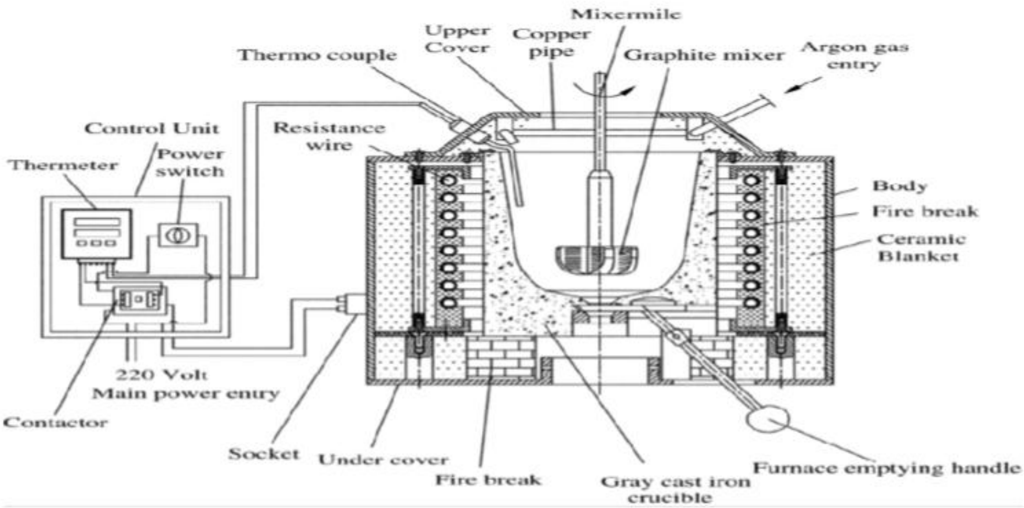


FIGURE 1 STIR CASTING SET UP

2.1 Stir casting process

Sharanabasappa et al, (2013) studied the mechanical properties of fly ash and alumina reinforced aluminium alloy (LM25) and they studied the specimen preparation by the process of stir casting where AMMCs are prepared by this process in an induction furnace. In this process LM25 is taken in flakes in a crucible and heated to 850^o C. At 400^{o}C fly ash and Al_2O_3 reinforcements are added at proper weight%. Then both the matrix and reinforcement contents are stirred at 600rpm for about 3-5minutes and a small amount of magnesium is added in order to improve the property of wettability [9].

B.Divakara Baligaet al, studied the machinability and corrosion behaviour of Al-Si-Mg alloy treated with master alloys and they studied the preparation of AMMCs at 770^{o}C [10]. Mr.Prasanna et al, studied on mechanical properties of silicon carbide, E-glass and red mud reinforced Aluminium (LM25) composite and they found that the specimen were prepared by stir casting technique and such specimen were Aluminium-LM25, SiC, E-glass and red mud. In this method, they studied the reinforcements were stirred at 300 rpm when the temperature is raised to 800^{o}C[11].

Akhilesh et al, analysed the property of Aluminium (LM25) metal matrix composite and here the matrix is (Al 356/LM-25) and SiC as reinforcement. They used the technique of liquid metal stir casting and first the aluminium was melted in a clay crucible which has capacity of 10kg. After that, stirring helps in binding or matrix mix the material together, overall it was done by impeller driven by an electrical motor which was maintained at 350rpm. In this analysis, the main significance is that they done the process of degassing where hydrogen entrapment was avoided by passing nitrogen gas to the molten metal by sulphuric acid. The process was done for about 20 minutes, as soon as the temperature reaches 760°C, the composite was poured to centrifugal mould. Thus, in this process sulphuric acid acts as purifier [12].

Basavaraju et al, studied on mechanical properties and Tribological characteristics of LM-25/ graphite/SiC and LM-25/fly ash/SiC hybrid MMC's and in this study the Lm-25 ingot was melted in electric furnace and the temperature was maintained at 800°C, silicon carbide, fly ash was prepared for various weight % composition. The specimens were prepared by ASTME standards to tensile, hardness, wear and hardness tests [13]. Shakeela et al, experimented on the predictive machinability of LM-25 Aluminium alloy in CNC turning operation with the help of Taguchi's technique and they investigated that the specimen was prepared by electric furnace which is maintained at 850°C and finally the mixture was poured to die of diameter of 30mm and length of 100mm [14].

3. RESULTS AND DISCUSSIONS

3.1Mechanical properties of Aluminium LM-25 MMCs

Prasanna et al, reported the tensile tests were conducted by Universal Testing Machine (UTM). The tensile properties of a specimen have three different compositions such as,

1. Specimen having constant weight % of red mud and SiC and varying weight% of E-glass,

2. Specimen having varying weight% of red mud and constant weight% of E-glass and SiC,

3. Specimen having varying weight% of SiC and constant weight% of red mud and E-glass.

From the above three tensile tests specimen composition, the (3) gives the better results which is shown in the table1, and it illustrates that addition of SiC at limited weight% improves the tensile strength and excess quantity reduces the value of mechanical property, because of the poor wettability [15].

TABLE 2: TENSILE PROPERTIES OF A SPECIMEN HAVING VARYING WEIGHT% OF SIC AND CONSTANT WEIGHT% OF RED MUD AND E-GLASS.

LM 25(BASE)	E-glass	SiC	Red Mud	Tensile strength(MPa)
93	1	3	3	191
90	1	6	3	216
87	1	9	3	229

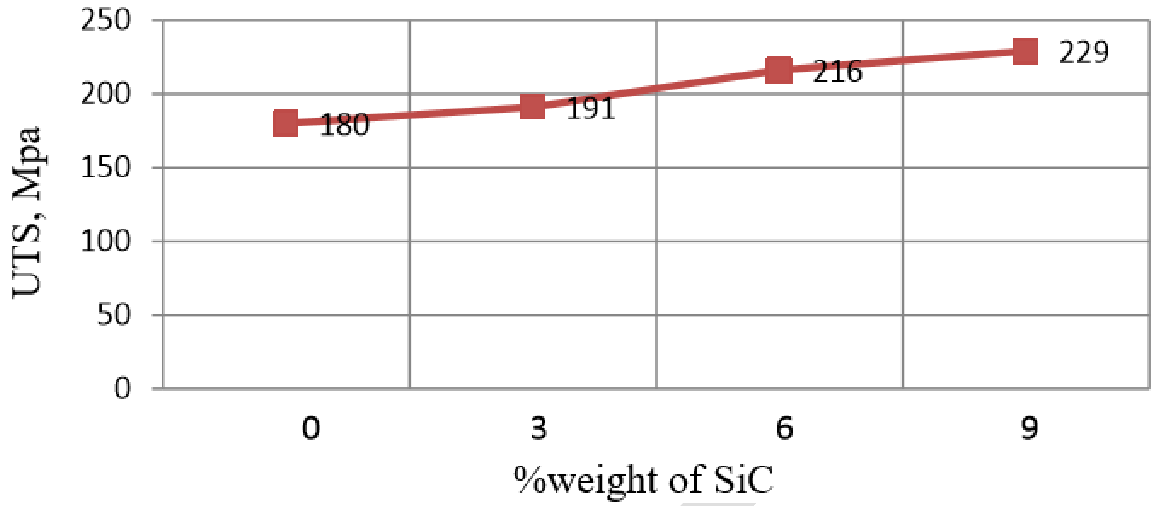


FIGURE 2 TENSILE PROPERTIES OF A SPECIMEN HAVING VARYING WEIGHT% OF SIC AND CONSTANT WEIGHT% OF RED MUD AND E-GLASS.

Sharanabasappa et al, observed the change in tensile strength by increase in weight% of Al_2O_3 and they also found that tensile strength comes down and it is because of wettability of AMMC's. Radhika et al, observed the tensile property of LM-25/SiC/aAl_2O_3 composites. The test was carried out by UTM and observed that tensile property is improved by increase in weight% of reinforcement [16].

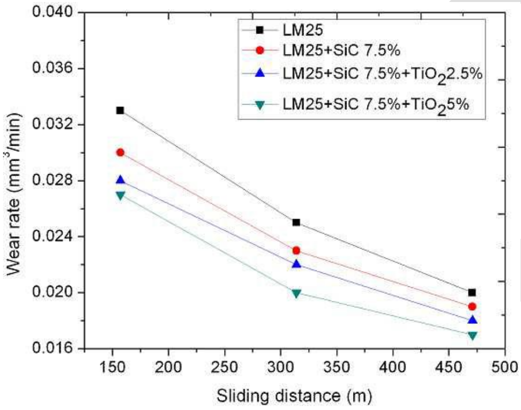
Basavaraju et al, studied the mechanical properties of two different reinforcements, LM-25/ graphite/SiC and LM-25/fly ash/SiC. For the first composite, Al LM-25 is having less strength compared with the second one. Thus initially 2% of SiC was added and found that the strength was improved from the former. Then it was further increased to 2% of SiC, which reduces the strength. From the series of investigation, it was found that whenever there is increase in weight % of SiC the tensile strength decreases, hence 2% SiC gives optimum strength compared to other weight % composition such as (4%,6%,8%)of SiC. They investigated on other reinforcements, instead of graphite they experimented with fly ash. When fly ash was added (2% weight) the tensile strength was greater, in addition with 2% weight of SiC. Thus in this reinforcement also, only for 2% SiC and 2% fly ash the tensile strength was improved and better rather than higherweight % of SiC(4%,6%,8%) .

R.Surendran et al, studied the Tribological behaviour of LM-25 Aluminium alloy reinforced with Nano Aluminium Oxide. Tensile test was conducted and it was found that tensile strength increases with increase in weight% of NanoAl_2O_3[17]. DivakaraBaliya et al, studied the machinability and observed the factors such as cutting force, power consumption, temperature, surface finish. They observed surface roughness and cutting force as machinability index. They found that the speed,feed, depth of cut effect on the cutting force for cast aluminium. For all the speed of cast aluminium alloy the cutting force was greater than speed of grain refined and modified samples. Similarly for feed and depth of cut, cutting force is greater for cast Aluminium alloys than for grain refined modified samples.

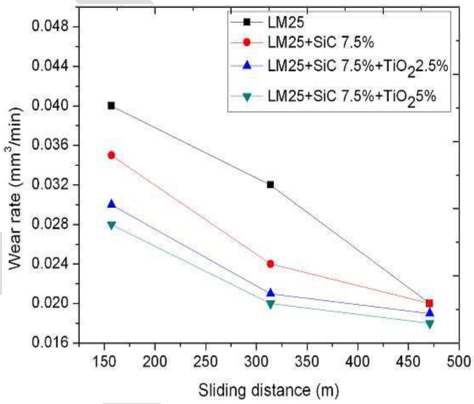
3.2 Wear behaviour of Aluminium LM-25 MMC's

Ramachandra et al, investigated wear and friction behaviour of Aluminium matrix composite with Fly ash reinforcement. They observed wear behaviour of the composite increases with increase in weight% of fly ash, where the wear rate decreases by increase in load and sliding velocity [18]. Md.AzharFarooqManiyar et al, studied on microstructure and Tribological behaviour of LM-25/SiC/mica- hybrid MMC's. It was found that increase in wear is improved by reducing the load. Here the 10% SiC and 2% mica is the optimum weight% mixture for ideal purpose. Hence the material tends to wear up to 5% of SiC [19]. S.K.Chaudhary et al, analysed wear performance with pure LM-25 and LM-25 with reinforcements such as SiC,TiO_2 by varying weight %. Figure1 represents the Lm-25 alloy under dry sliding conditions and it was the effect of load and sliding distance on wear rate.

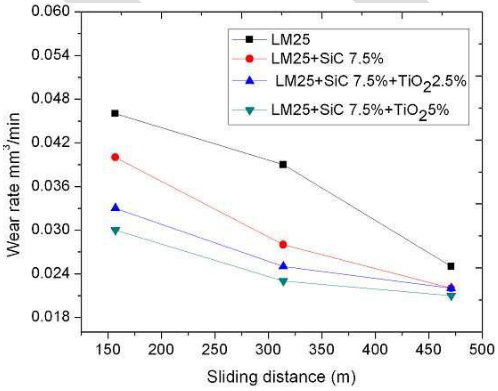
From the Figure 3, it was inferred that for various composition by weight %,the wear rate increases by increasing load whereas increase of sliding distance reduces the wear rate under various load conditions, the wear rate is varies for different composition and combination of reinforcements in AMMC[20].



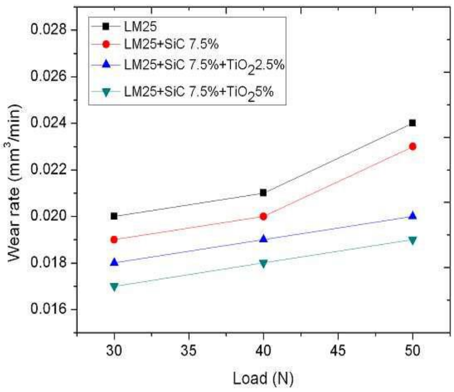
(a)29.43N



(b) 39.24 N



(c) 49.04N



(d) at a maximum sliding distance of 628m

FIGURE 3 WEAR RATE OF UNREINFORCED ALLOY AND COMPOSITES AT APPLIED LOADS OF (A) 29.43N (B) 39.24N (C) 49.05N AS A FUNCTION OF SLIDING DISTANCE (D) AT THE END OF MAXIMUM SLIDING DISTANCE (628 M) AS A FUNCTION OF VOLUME PERCENTAGE OF REINFORCEMENT.

Radhika et al, observed the effect of sliding velocity on wear rate. It was found that wear rate decreases as the velocity increases. It was plotted in the graph shown in Figure 4 that, wear resistance increased as weight% of reinforcement is increased [21].

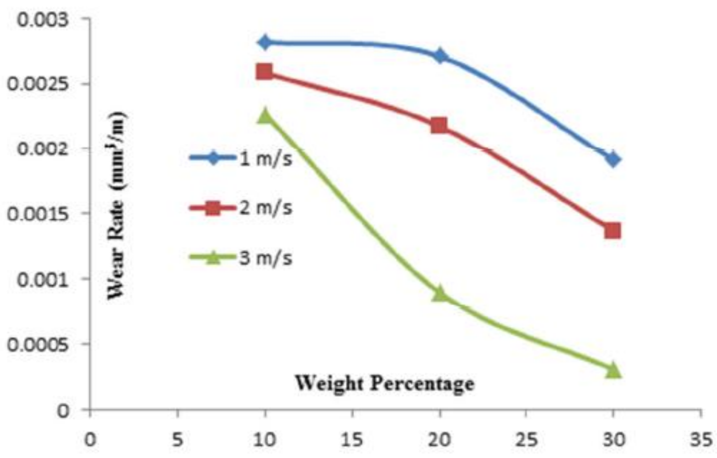


FIGURE 4 EFFECT OF SLIDING VELOCITY ON WEAR RATE.

Sudharshan et al, observed the effect of load on wear rate, where coefficient of friction increases as the load increases. In addition to this, it also increases the wear rate due to increase in temperature.

The Figure 5 shown below, gives the wear rate behaviour where the weight% of the reinforcement increases, the wear rate decreases. Therefore to improve the wear resistance increase the weight% of reinforcements and contact area of reinforcements [22].

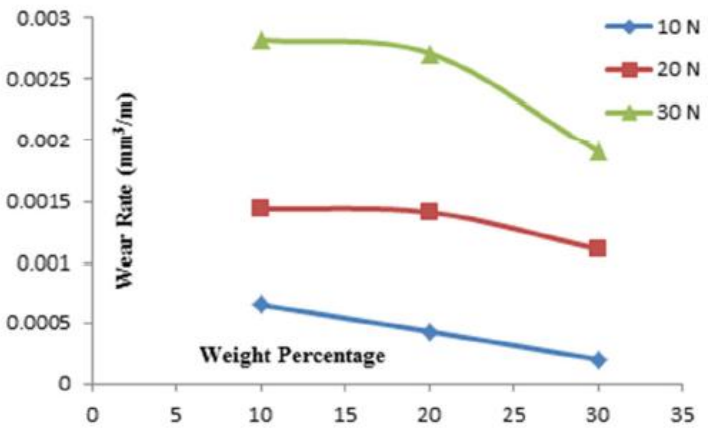
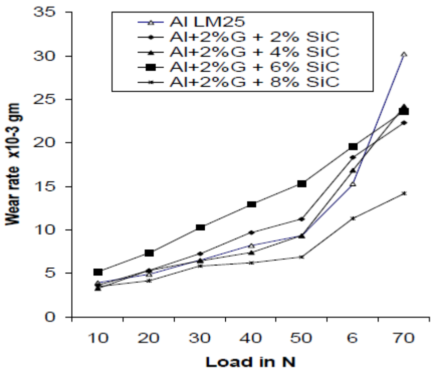


FIGURE 5 EFFECT OF LOAD ON WEAR RATE

Basavaraja et al, studied the Tribological behaviour of LM-25/graphite/SiC and Lm-25/fly ash/SiC. The wear rate is plotted in the form of graph as shown in Figure 6 and 7.

It was observed that wear rate is highest in 8% SiC composition, which is more brittle and best result is observed in the composition of 2% graphite and 2%SiC. Therefore it was concluded that lesser the weight% composition of SiC and graphite better the wear behaviour.



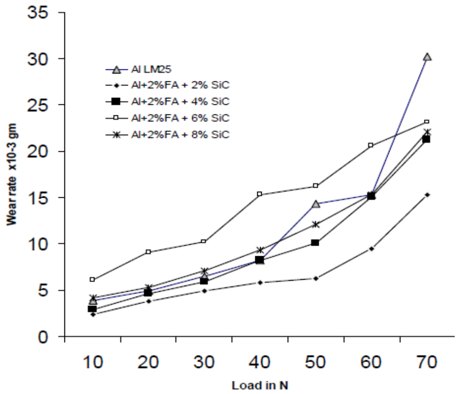


FIGURE 6 FIGURE 7

FIGURE 6 WEAR CHARACTERISTICS OF AL/G/SIC MMC

FIGURE 7 WEAR CHARACTERISTICS OF AL/FA/SIC MMC

3.3 Micro structure of Aluminium LM-25 MMC's

Sharanabasappa et al, analysed the micro structure using Scanning Electron Microscope (SEM),and it was seen that the phases were uniformly distributed in the metal matrix, its microstructure was examined and the Figure 8,9 and 10 were given below [23].

D.G.Mallapur et al and V.P.Patel et al, investigated the microstructure of LM-25 alloy with reinforcements. They observed the microstructure of cast Al LM-25 alloy, grain refined and modified Aluminium alloy and grain refined, modified and heat treated Aluminium alloy as shown in Figure 11-13. It was observed that in the absence of grain refiner, modifier and T6 heat treatment, it consists of dendritic structure of α-Aluminium along with coarse acicular eutectic silicon. It was found that eutectic silicon was evenly distributed with fibrous structure, (0.5% of Al-10Ti grain refiner and 0.2% of Al-10Sr modifier). The microstructure of alloy with 0.5% grain refiner, 0.2% modifier and T6 heat treatment, eutectic silicon was still reduced and more fibrous [10,13].

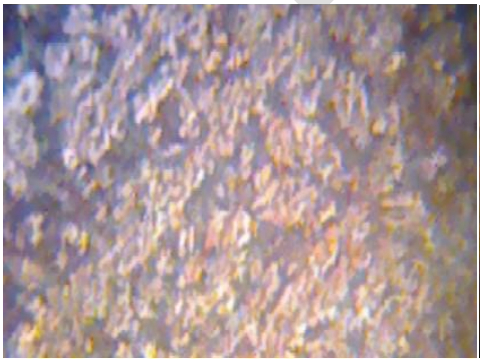


FIGURE 8 FIGURE 9

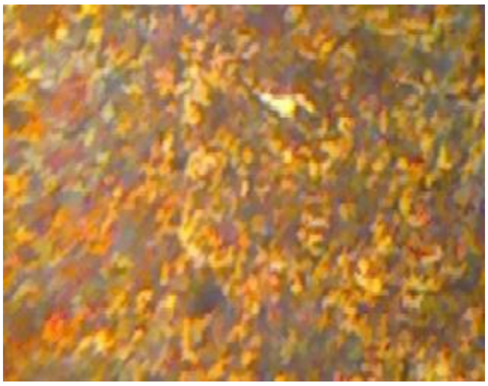


FIGURE 10

FIGURE 8 MICRO STRUCTURE OF LM25 WITH 5%AL_2O_3 AND 3% FLY ASH
FIGURE 9 MICRO STRUCTURE OF LM25 WITH 10% AL2O3 AND 3% FLYASH
FIGURE 10 MICRO STRUCTURE OF LM25 WITH 15 % AL2O3 AND 3% FLYASH

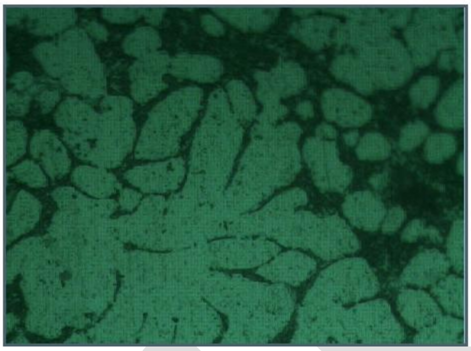


FIGURE 11

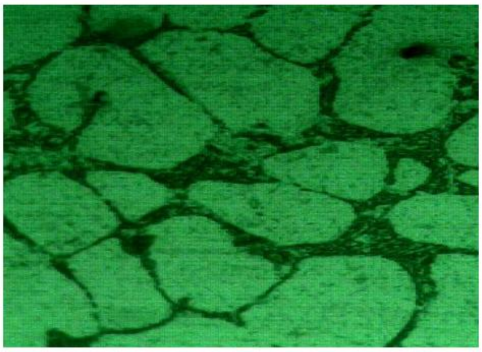


FIGURE 12

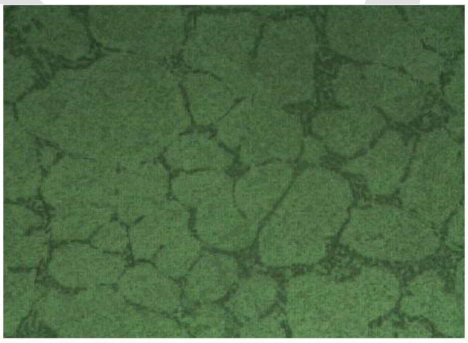


FIGURE 13
FIGURE 11 AS-CAST SPECIMEN
FIGURE 12 GRAIN REFINED AND MODIFIED
FIGURE 13 GRAIN REFINED, MODIFIED AND T6 HEAT TREATED

4 CONCLUSION

1. From various studies undertaken by authors, it is concluded that tensile and hardness properties increases with increase in weight % of Al_2O_3 and also inferred that poor wettability is one of the drawback due to higher weight% of reinforcement. Therefore, it can be concluded that the strength of the composite decreases beyond certain limit. It was observed and concluded that maximum tensile strength is obtained in 2% reinforcement of SiC.

2. There was a reduction in the wear rate due to increase in the percentage of reinforcements, whereas wear rate increases due to increase in load. In addition to this, coefficient of friction decreases when the load increases as well as increase in particle reinforcement causes decrease in coefficient of friction. It was concluded that the wear rate increases due to an increase in sliding velocity whereas there was reduction in wear rate with constant sliding distance.

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