A Study on Mechanical and Tribological Properties of Al LM6 MMCs Reinforced with Nano SiC, Fly Ash and Red Mud

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Abstract— In this paper; fabrication of aluminum metal matrix composite (MMCs) is prepared by liquid metallurgy route (stir casting technique).The objective of this experimental investigation is to produce two different metal matrix composite (MMCs) specimens using Al Lm6 as a base material which reinforced with silicon carbide, fly ash, red mud whose grain size is in nano size i.e sic-80 nano meter (nm), fly ash-100000 nm or 100 microns (µm), redmud-120000 nm or 120 µm and then studying its mechanical and tribological properties such as tensile strength, impact strength, hardness and wear behavior of produced test specimen. Experiment is conducted by varying weight fraction of sic, fly ash, red mud and then testing its tensile strength, impact strength, hardness, wear behavior. The result reveal that the optimum tensile strength of the hybrid composite is obtained constant as the weight percentage of red mud varies from (2% to 4%) and also results in higher tensile strength. The result also shows that increased in addition of fly ash improve the impact strength and also improve wear resistance.

Key words: Nano SiC, Al LM6 MMCs, Fly Ash

I. INTRODUCTION

Composite material is the material having two or more distinct phases like matrix phase and reinforcing phase and having bulk properties significantly different from those of any of the constituents present in the matrix material. Composite materials are preferred over other metals and non metals because of some favorable properties they are having. The favorable properties are, high stiffness and high tensile strength, low density, high temperature stability, and also in some of the applications electrical and thermal conductivity properties are also taken into consideration, the properties like coefficient of thermal expansion, corrosion resistance are also low with improved wear resistance. To improve fuel efficiency in automobiles the bodies are manufactured with the composite materials, so that the automobile body mass can be kept low by improving fuel efficiency. Mainly aluminum composite materials are having more scope because of its light weight, durability, machinability; availability on earth and cost is more attractive compared to other competeting materials. However the scope of these properties can be extended by using Al matrix composite materials.

Fly ash which is used in this fabrication work is in grain size of 100 microns or 100000 nm is one of the residues generated in combustion and comprises the fine particles that rise with flue gases ash which does not rise is termed as bottom ash. Fly ash is generally captured by electrostatic preceptors or other particle filtration equipment before flue gas reaches the chimney of coal firepower plant. fly ash include substantial amount of silicon dioxide (sio2) and calcium oxide (cao).it is one of the most inexpensive and low density reinforcement available in larger quantities as waste product during combustion of coal in thermal power plant .in these study fly ash used is of grain size about 100000 nm or 100 microns silicon carbide (sic) is highly wear resistance and also has good mechanical properties with low density including high temperature strength and thermal shock resistance.

Silicon carbide also knows as carborundum is a compound of silicon and carbon it was originally produced by a high temperature electrochemical reaction of sand and carbon. sic is an excellent abrasive has been produced today the properties it is used in abrasives, refractories, ceramics and numerous high performance application for these fabrication work sic which is used is in grain size of 80 nm

Red mud emerges as the waste material during the production of alumina from bauxite in bayer's process. The red color is caused by the oxidized iron present, which can make up to 60% of the mass of the red mud. it comprises oxides of iron, aluminum, titanium and silica along with some other minor constituents. in these fabrication work red mud which is used is in grain size of 120 micron or 120000 nano meter (nm).

The objective of present work is to produce hybrid component of Lm6/sic/fly ash/red by stir casting method. And determine the effect of addition of silicon carbide, fly ash and red mud on mechanical and tribological properties of aluminum Lm6 MMCs.

Before preparing the aluminum MMCs material we have studied some paper in which addition of sic, fly ash, red mud into aluminum LM6 metal alloy and mechanical properties were studied few of them are as follows;

Neelima devi. c, mahesh.v, selvaraj. n 97(7) studies on mechanical characterization of aluminum silicon carbide composite. They found that, the maximum tensile strength has been obtained at 15% sic ratio. This indicates that the aluminum silicon carbide composite material is having less weight and more strength; it is very much useful in practical aerospace applications.

Prashant kumar suragimath (8) studied the mechanical properties of aluminum alloy lm6 reinforced with sic and fly ash and found that the wear resistance tends to increase with increase in addition of fly ash in lm6/sic hybrid composite.

Mr. vijay kumar s maga ,bs motagi 9(1) reported that the production of al lm6 mm reinforced with varying weight fraction of sic/fly ash/red mud. the result shown that the increase in addition of fly ash giving better result when compared to red mud.

II. EXPERIMENTAL DETAILS

A. Material Preparation

The present investigation was carried out on LM6 Al alloy composition as shown in table1. The material was cast in the

form of round cylindrical rods of diameter 15mmx 125mm in length by adding sic, fly ash and red mud as reinforcements by various weight percentages. The cast rods were rapidly cooled to room temperature by knocking them out, 5mins after casting. Table 2 shows the composition of fly ash.

B. Specimen Preparation and Experimental Methodology

The specimens are prepared by machining the stir casted parts as per American standard ASTM (A370). For stir casting induction furnace is used. First the base metal is taken in a furnace and heated to 600°c.when base metal melts at that temperature the preheated reinforcements are added to the molten base metal. Then to have self stirring process temperature of the furnace is raised to 800°c and also the stirring is done with the help of stirring mechanism at 300 rpm. Figure (1) shows the step by step casting and specimen preparation processes.

III. Results and Discussion

A. Tensile Testing

Tensile test is carried out with the help of universal testing machine (UTM).the fundamental material science testing, in which a sample is subjected to uniaxial tension until failure. The properties that are directly measured via tensile test are maximum elongation, ultimate tensile test and reduction in area. The specimens were prepared as per ASTM (a370). Table 5 shows the result for tensile test. Among all the tested samples. Sample (2) results in higher tensile strength up to 164.9 N/Mm^2

Al Lm6+3%Sic+2%Fly Ash+4%Redmud.

B. Impact Testing

An impact test is carried out with the help of charpy v-notch testing machine.

A standardized high strain rate which determines the amount of energy absorbed by material during fracture these test is carried out at room temperature the reading was taken by breaking specimen due to impact of pendulum. Table 6 shows the result of impact test .among all tested samples. The sample (5) results in high impact strength up to 65.33 joules

Al Lm6+3%Sic+6%Fly Ash+2% Red Mud

C. Wear Test.

Wear is a process of material removal phenomena. The prepared lm6 al alloy with varying weight percentage of sic & fly ash and red mud composites were subjected to wear test under dry sliding condition. The test was conducted on 8mm dia and 22 mm long cylindrical specimens. The wear tests were carried out at room temperature for 5mins on the rotating disc, made of en 32 steel discs.

The test parameters used were as follows;

- Track dia: 60mm
- Speed: 500 rpm
- Load: 30 and time: 5mins

Among all the tested samples. Sample (5) has high wear resistance i.e Al Lm6+3%sic+6%fly ash+2%red mud .table 7 shows the result of wear test.

D. Hardness Test

These test is carried out by brinell hardness equipment .the brinell scale characterizes the indentation hardness of materials through the scale of penetration of an indenter, loaded on a material test-piece. it is one of several definitions of hardness in materials science. The typical test uses a 10 millimeters (0.39 in) diameter steel ball as an indenter with a 3,000 kgf (29 kn; 6,600 lbf) force. For softer materials, a smaller force is used; for harder materials, a tungsten carbide ball is substituted for the steel ball. Among all the tested samples. The sample (6) results in improved hardness up to 260 BHN. Table 8 shows the result of harness test

Al Lm6+6%Sic+2%Fly Ash+2%Redmud.

IV. Figures and Tables

Figure 1 shows step by step casting process.

A. Step 1:

Lm6 is taken in an induction furnace as shown in below fig 1.1

B. Step 2:

The melting is done by raising furnace temperature up to 600°C as shown in below fig 1.2

C. Step 3:

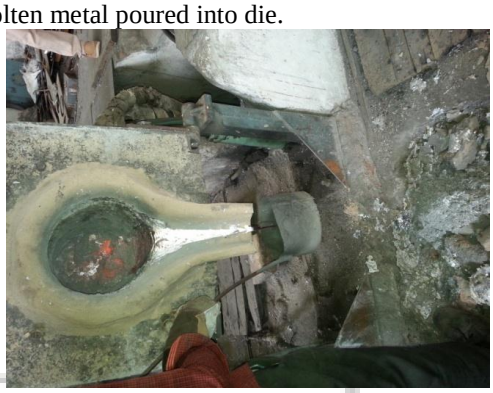
Pre heated (300°C) reinforcements are added to the molten metal one by one and stirred as shown in below fig 1.3

D. Step 4:

The cast iron die pre heated (100°C) as shown in below fig 1.4

E. Step 5:

Molten metal is pouring into the laddel first, fig 1.5. Then this molten metal poured into die.

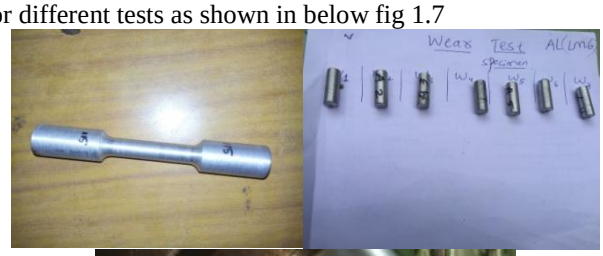


F. Step 6:

Stir casted parts are taken out from the die after 10 minutes of pouring and naturally cooled as shown in below fig1.6

G. Step 7:

The Casted parts are machined to get the required specimens for different tests as shown in below fig 1.7



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

Table 1: Chemical Composition of LM6.

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 2: Chemical Composition of F.A.

Component (Elements)	% Weight	Constituents (Compound)	Weight %
AL	7.67	AL_2O_3	14.49
SI	3.22	SIO_2	6.89
CA	3.67	CAO	5.13
TI	12.37	TIO_2	20.693
FE	30.70	FE_2O_2	39.49
CU	2.94	CUO	3.68
ZN	2.14	ZNO	2.68
O	32.09		
TOTAL	100	TOTAL	100

Table 3: Chemical composition of red mud in element and compound form

Sample	Composition
1	LM6+3%SIC+2%FLY ASH+2%RED MUD
2	LM6+3%SIC+2%FLY ASH+4%RED MUD
3	LM6+3%SIC+2%FLY ASH+6%RED MUD
4	LM6+3%SIC+4%FLY ASH+2%RED MUD
5	LM6+3%SIC+6%FLY ASH+2%RED MUD
6	LM6+6%SIC+2%FLY ASH+2%RED MUD
7	LM6+9%SIC+2%FLY ASH+2%RED MUD

Table 4: Sample specification

Sample	Tensile Strenght N/Mm^2			Average
	1	2	3	
1	163.64	173.810	156.35	164.6
2	166.73	162.521	165.45	164.9
3	139.31	135.012	180.854	151.72
4	177.86	142.021	125.393	148.42
5	164.53	119.24	133.78	139.18
6	158.67	129.86	138.31	142.28
7	102.713	106.059	160.999	123.257

Table 5: Results of Tensile test.

Sample	Energy Absorbed(Joules)			Average (Joules)
	1	2	3	
1	58	62	56	58.66
2	56	56.5	55	55.83
3	55.5	54	54.5	54.66

4	62	60.5	60	60.83
5	64	66	66	65.33
6	64	62.5	62.5	63
7	60.5	64	62	62.166

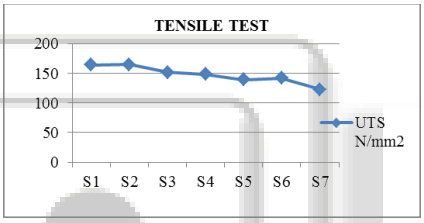
Table 6: Results of Impact test.

Sample	Wear In (μm)	Wear Rate In Mm^3/M	Wear Resistance M/Mm^3
1	186.03	18.782×10^{-3}	53.24
2	139.84	14.3×10^{-3}	69.75
3	87	8.92×10^{-3}	112.05
4	306	33.92×10^{-3}	29.42
5	41	4.92×10^{-3}	202.96
6	257	26.113×10^{-3}	38.29
7	401	42.62×10^{-3}	23.458

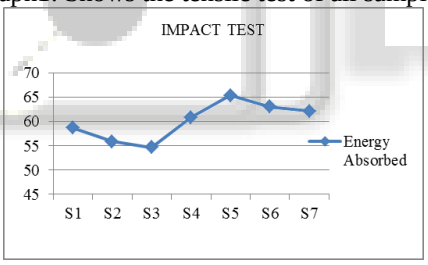
Table 7: Results of Wear Test

Sample	Hardness Value(BHN)
1	62
2	69
3	251
4	69
5	218
6	260
7	218

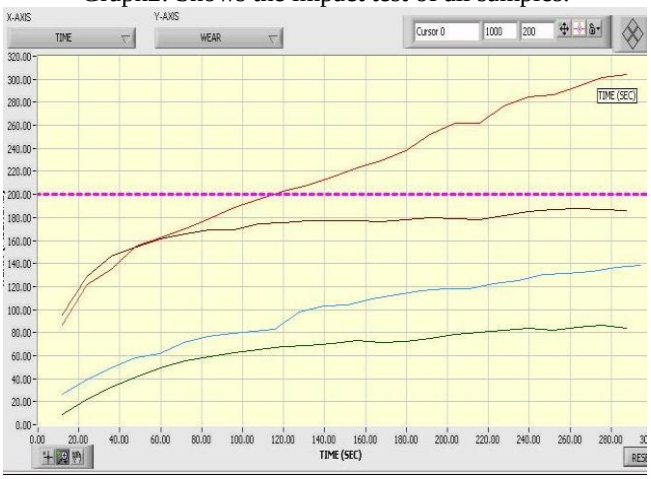
Table 8: Results of hardness test



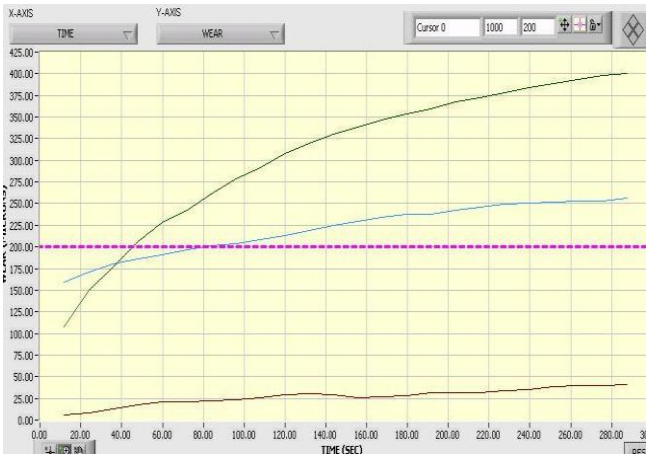
Graph1: Shows the tensile test of all samples.



Graph2: Shows the impact test of all samples.



Graph3: shows the wear test of sample 1,2,3,4
AL LM6+3%SIC+2%FLY ASH+2%RED MUD
AL LM6+3%SIC+2%FLY ASH+4%RED MUD
AL LM6+3%SIC+2%FLY ASH+6%RED MUD
AL LM6+3%SIC+4%FLY ASH+2%RED MUD



Graph4: shows the wear test of sample 5, 6, 7
AL LM6+3%SIC+6%FLY ASH+2%RED MUD
AL LM6+6%SIC+2%FLY ASH+2%RED MUD
AL LM6+9%SIC+2%FLY ASH+2%RED MUD

V. CONCLUSION

From the experiments conducted to study the effects of adding various volumes fractions of sic, fly ash & red mud, following conclusions can be drawn.

- Composite material Lm6 al alloy reinforced with nano sic, fly ash, red mud was successfully casted by stir casting method.
- In this study the optimum tensile strength is obtained in sample (1 and 2) is found to be constant as the red mud varies from 2% to 4% with constant fly ash and sic content (3%sic and 2%fly ash) . Further from the sample (3) if weight percentage of red mud varies from 4% to 6% by maintaining constant fly ash and sic content (3%sic and 2%fly ash) the tensile strength decreased as compared with the sample (1) and (2).
- Tensile strength of the sample (4) rises as weight percentage of fly ash varies from 2% to 4% by maintaining constant red mud and sic content (3% sic and 2% red mud) . further from sample (5) tensile strength slightly drops [as compared with the sample (4)] in which weight percentage of fly ash varies from 4% to 6% and by maintaining constant red mud and sic content (3% sic and 2% red mud) .
- Tensile strength of the sample (6) rises as weight percentage of sic varies from 3% to 6% by maintaining constant red mud and fly ash content (2% red mud and 2%fly ash). Further from sample (7) tensile strength drops [as compared with sample (6)] in which weight percentage of sic varies from 6% to 9% by maintaining constant red mud and fly ash content (2% red mud and 2%fly ash).
- The best result of tensile strength has been obtained in sample (2) at weight percentage of Lm6+3%sic+2%fly ash+4%red mud
- The impact strength of the sample (1) is found to be increased at 2% percentage of red mud by keeping constant fly ash and sic content (3%sic and 2%fly ash). Further from the sample (2) if weight percentage of red mud varies from 2% to 4% by keeping constant fly ash and sic content (3%sic and

2%fly ash). there is a slightly drop in a impact strength as compared to sample (1).similarly from the sample 3 if weight percentage of red mud varies from 4% to 6% by keeping constant fly ash and sic content by (3%sic and 2%fly ash). The impact strength again drops slightly as compared to sample (1) and sample (2).

- In a sample (4) impact strength found to be lesser as compared to sample (5). In sample (4) weight percentage of fly ash varies from 2% to 4% by keeping constant weight percentage of sic and red mud content (3%sic and 2% red mud). Further from sample (5) impact strength rises as the weight percentage of fly ash varies from 4% to 6% [as compared to sample 4]. And keeping constant weight percentage of sic and red mud content (3%sic and 2% red mud).
- The impact strength of the sample (6) is found to increase as the weight percentage of sic varies from 3% to 6% and by maintaining constant fly ash and red mud content (2% red mud and 2%fly ash). further from the sample (7) if weight percentage of sic varies from 6% to 9% by keeping fly ash and red mud content constant (2% red mud and 2%fly ash). There is a slightly drop in an impact strength as compared to sample (6).
- The best result of impact strength has been obtained in sample (5) at weight percentage of Lm6+3%sic+6%fly ash+2%red mud.
- The hardness of the sample (1,2,3) found to be increasing as the weight percentage of red mud varies from 2% to 4% and 4% to 6% and by keeping constant weight percentage of fly ash and sic content (3%sic and 2%fly ash) .
- The hardness of sample (4) found to be lesser [as compared with sample (5)] in which weight percentage of fly ash varies from 2% to 4% and by keeping constant weight percentage of red mud and sic content(3%sic and 2%red mud).further in sample (5) hardness is found to be increased by varying weight percentage of fly ash from 4% to 6% and by keeping constant weight percentage of red mud and sic content(3%sic and 2%red mud)
- The hardness of sample (6) is founds to be increased by varying weight percentage of sic from 3% to 6% and by keeping constant fly ash and red mud content(2% fly ash and 2% red mud).further from sample (7) hardness is found to be slightly decreased [as compared with sample (6)] in sample (7) the weight percentage of sic varies from 6% to9% and maintaining constant fly ash and red mud content(2% fly ash and 2% red mud).
- The best result of hardness has been obtained in sample (6) at weight percentage of Lm6+6%sic+2%fly ash+2%red mud.
- The wear resistance of the sample(1,2,3) found to be increasing as the weight percentage of red mud varies from 2% to 4% and 4% to 6% and by maintaining constant weight percentage of fly ash and sic content (3%sic and 2%fly ash) .
- In a sample (4) wear resistances found to be decreased [as compared with sample (5)]. in sample (4) weight percentage of fly ash is varies from 2% to 4% by keeping constant red mud and sic content (3%sic and 2% red mud).further in a sample (5) wear resistance increases by varying weight percentage of fly ash from 4% to 6% and also maintaining constant red mud and sic content (3%sic and 2% red mud).
- In sample(6) wear resistance found to be increased by varying weight percentage of sic from 3% to 6% and by keeping constant red mud and fly ash content (2%fly ash and 2% red mud).further in the sample (7) as weight percentage of sic varies from 6% to 9% wear resistance slightly drops [as compared with sample (6)] by keeping constant red mud and fly ash content (2%fly ash and 2% red mud).
- The good wear resistance has been obtained in sample (5) at weight percentage of Al Lm6+3%sic+6%fly ash+2%red mud

VI. Scope of Future Work

- Same metal matrix composites can be manufactured by using other manufacturing techniques like spray casting, powder metallurgy method etc. and results can be compared with stir casting technique.
- Further studies can be done by using fiber composite material instead of using particulate composite materials
- Further studies can be done by varying different weight percentages of reinforcements.
- Further studies can be done by varying reinforcement grain size.

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