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An Experimental Investigation of Metal Matrix Composites of Aluminium (Lm6), Boroncarbide and Flyash

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ABSTRACT

One of the most widely used composites is the aluminium based composites. Aluminium matrix composites refer to the class of low weight high performance aluminium is a main material. The reinforcement in AMCs may be in the structure of continuous and it also be in the form of discontinuous fibres, whiskers or particulates with volume fractions ranging from a few percent to 70%. Reinforcements commonly used in aluminium matrix composites have been extended to include organic wastes such as rice waste ash, coconut cover ash, palm oil fuel ash, and fly ash and sugar cane bagasse. Ceramic materials being used as reinforcement consists of carbides, borides, nitrides and alumina. These have been reported to produce expected physical and mechanical properties in aluminium based composites. In this experimental study the composite obtained by stir casting method by the ingredients of aluminium, boron carbide, fly ash in the different proportions. then the composite subjected to various testing machine such as pin on disc, dilatometer, abrasion testing machine to find out co efficient of friction, wear loss, wear rate for different combinations and results were compared.

INTRODUCTION

Composite material is a element composed of more than one distinct phases (matrix phase and reinforcing phase) and having huge characteristics significantly different from those of any of the constituents. A metal matrix composite has been identified as attractive materials for the wide range of applications in the field of structural design, electronics system and electronic packaging (Vengatesh, D., V. Chandramohan, 2014). Aluminium alloys reinforced with various ceramics such as silicon carbide and aluminium oxide are a unique class of advanced composite material developed for use in aerospace and commercial applications. Compared with unreinforced metals, MMC exhibits significant improvements in strength and elastic modulus, wear resistance, fatigue resistance and damping capacity, in addition to high temperature mechanical properties and low thermal expansion. A low CTE and high thermal conductivity are expected for for applications such as electronic heat sinks and space structures (FarshadAkhlaghi, S., Mahdavi, 2011). Furthermore low density is desirable for aerospace applications; particularly electrical structural applications. One of the most widely used composites is the aluminium based composites. Aluminium matrix composites refer to the class of low weight high performance aluminium centric materials. Reinforcements commonly used in aluminium matrix composites have been extended to organic wastes such as rice waste ash, coconut cover ash, palm oil fuel ash, fly ash and sugar cane. Ceramic materials being used as reinforcement include carbides, borides, nitrides and alumina. These have been reported to produce expected physical and mechanical properties in aluminium based

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composites. Stir casting is a effective method for production of aluminium metal matrix composites because of their simplicity and ease of manufacture.

II. Elements Of Composite Materials:

Aluminium:

Aluminium is a metal in the boron group with symbol Al and atomic number 13. It is a white, soft, ductile metal. Aluminium is the third natural abundant element and the most popular metal in the Earth's crust. It makes up about 8.0% by mass of the Earth's solid surface. Aluminium metal is so chemically reactive that native specimens are rare and limited to extreme reducing environments. The aluminium is obtained from bauxite ore.

Boron Carbide:

Boron carbide is an highly hard boron–carbon ceramic material used in tank armor, bulletproof vests, as well as many industrial applications. It is one of the tough materials known, behind cubic boron nitride and diamond.

The capacity of boron carbide to absorb neutrons without forming long lived radoactivity nuclues makes it attractive as an absorbent for neutron radiation created in nuclear power plants. Nuclear applications of boron carbide include radiation shielding, control rod and shut down pellets. In control rods, boron carbide is often sintered and coated to increase its surface area.

Flyash:

Fly ash, is one of the byproducts generated in combustion of solid fuel, and comprises the fine particles that rise with the flue gases. Ash which is settled in down called bottom ash. In an industrial context, fly ash usually refers to ash produced during combustion of solid fuel such as coal. Fly ash is generally absorbed by electrostatic precipitators or soot blower before the flue gases reach the chimneys of coal-fired power plants.

III. Description Of Equipments:

Stir Casting:

In a stir casting method, the reinforcing materials are distributed into molten matrix by mechanical stirring. Stir casting of metal matrix composites was developed in 1968, when S. Ray introduced alumina particles into aluminium melt by stirring molten aluminium alloys contains the ceramic powders. In the Mechanical stirring, furnace is a main equipment of this process. The resultant composite materials, can be used for die casting, permanent mold casting, Stir casting is applicable for manufacturing composites with up to 30% volume fractions of reinforcement.

In recent years stir casting with a two-step mixing process is currently used. In this process, the matrix material is heated to above its saturation temperature so that the metal is totally melted. Then the molten metal is cooled down to a temperature between the liquid state and solid state and kept in a semi-solid state (Hamouda, A.M.S., 2007).

At this period, the preheated boron carbide and fly ash are added and mixed. The slurry is again subjected to heating up to liquid state and mixed thoroughly. In this two-step mixing process mostly used for fabrication of aluminium.

Pin On Disc:

In the pin-on-disk wear test, two specimens are used. One is a pin with a radius tip, is positioned perpendicular to the other, which usually a flat circular disk. Second a ball, rigidly held, is often used as the pin specimen. The test machine rotates either the disk specimen or the pin specimen to revolve about the disk center. The sliding path is a circle on the disk surface in two cases. The plane of the disk may be positioned either vertically or horizontally. Wear results may differ for different orientations. The amount of wear is calculated by either measuring length of both specimens before and after the test, or measuring weight of these two specimens before and after the test.

Dilatometer:

Dilatometer is a one which is used for measuring the coefficient of thermal expansion or expansion coefficient. It consists of quartz tube where the test specimen is placed.

Micro Abrasion Testing Machine:

Micro Abrasion wear testing machine is the type of ball crater testing machine which uses hardened stainless steel ball for wear testing.

It consists of motor which is coupled to the shaft and the maximum rotation speed is of about 500 rpm. In our project we selected the speed of 400 rpm as constant for wear testing. The performance of the wear test for the test specimen is considerations of three parameters such as load, speed and time

Characterization of wear produced by each kind of composite specimen was done using a micro abrasion wear tester. This test uses a SAE 52100 steel ball with 25mm diameter acting as a counter body during the wear test dragging over the sample surface of test specimen which is nothing that aluminium hybrid metal matrix composites.

Fig. 1: Pin on Disc Machine.

Table 1: Specifications of pin on disc machine.

PARAMATER	SIZE	UNIT
Pin Size	3,5,10&12 diameter	mm
Disc Size	Diameter 55 diameter Thick	mm
Disc Rotation Speed	0-1450	rpm
Wear Track dia Mean	30 to 90	mm
Load	10	Kg
Frictional Force	0-10	Kg
Temperature	Ambient to 550	^{0}C
Power	415/50/3	V/Hz/phase

Fig. 2: Dilatometer.

Table 2: Specifications of Dilatometer.

PARAMETER	DESCRIPTION
Sample Size	46mm with cross section 10mm
Temperature	1000^{0}C (max)
Heating elements	Silicon Carbide
Programmer	NIPPON
Thermocouple	K-Type
Resolution of LVDT	1 micrometre

Table 3: Specifications of Abrasion Testing Machine.

PARAMETER	SIZE	UNIT
Load Range	2 to 20	mm
Diamond Ball	15,20,25,32,40	mm
Metal Wheel	50	mm
Rubber Wheel	50	mm
Abrasive Paste	Silicon Carbide , Diamond	No unit
Motor	0.15/50-500	KW/rpm

The machine is capable of doing the wear test for the maximum load range of 20N and the testing apparatus consists of rubber wheel and metal wheel of size 50mm.Tests with three different durations were carried out allowing understanding micro abrasion evolution and failure mechanisms before and after perforation

The above Fig.No 4 describes the testing arrangement for micro abrasion wear testing the ball in the figure is nothing but stainless steel ball which used in the micro abrasion test.

Methodology:

The aluminium alloy LM6 is heated and melted in the melting furnace for the temperature of about 900^{0}C and aluminium alloy LM6 is cleaned with special kind of powder which is used to remove the scraps present in the aluminium alloy which is in the liquid state. Then reinforcement called boron carbide and fly ash is added to the aluminium alloy LM6 under three different proportions of 3%,6% and 9% which is nothing but 30 grams of boron carbide and fly ash and 60 grams of boron carbide and fly ash and 90 grams of boron carbide and fly ash is get stirred for three different cycles by stir casting at the speed of 300 rpm (Meena, K.L., 2013). Before mixing the reinforcement with aluminium alloy LM6 the reinforcements are preheated in the muffle furnace for the temperature of about 500^0C and then it is added to the aluminium alloy LM6. After getting the hybrid metal matrix composite made to pour inside the die of circular section which has the diameter of 22 mm and length 106 mm followed by the another dye which has the taper diameter of 33 mm and length 86 mm. Then it is allowed to cool for some time and the composite specimen is taken out and it is allowed to machining for the required dimensions (Arun, L.R., 2013). After stir Casting the hybrid composite in the form of the liquid state is taken by using the long handle shaped equipment where it is used to taken the composite material in the liquid state and it is made to poured inside the dye which has the diameter of 23 mm and length 108 mm .After pouring into the die the composite material is changed from liquid state into solid state and the composite material is allowed to cool for some time and the dye is made to open and the composite material is taken out which is in the form of solid state.

Fig. 3: Raw material of aluminium alloy LM6.

Fig. 4: Aluminium alloy Cut into small pieces weighted for 1.5 kg and dropped into melting furnace.

Fig. 5: Preheated boron carbide and fly ash.

Fig. 6: Stir casting of aluminium alloy LM6 and preheated reinforcement.

Fig. 7: Pouring the composite into the Dye.

A.Specimen Specifications for Pin on Disc:
Material Type:Aluminium Hybrid MMC Pin Diameter: 6mm Pin Length: 50mm

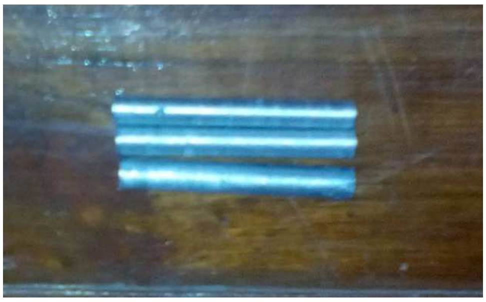

Fig. 8: Specimen for Pin on Disc.

B.Specimen Specifications for Dilatometer:
Material Type: Aluminium Hybrid MMC
Diameter of Test Specimen: 10mm
Length of Test Specimen: 44mm
Material Type: Round

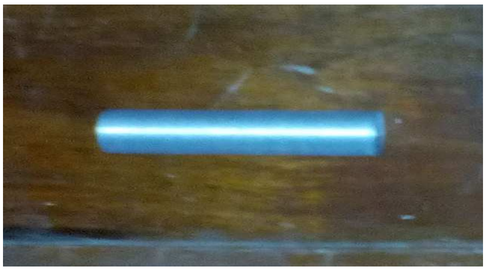

Fig. 9: Specimen for Dilatometer.

Specimen Specifications for abrasion testing:
Material Type: Aluminium Hybrid MMC
Diameter of Test Specimen: 23mm
Thicness of Test Specimen: 12mm

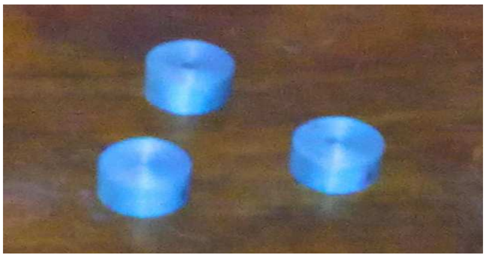

Fig. 10: Specimen for Micro Abrasion.

RESULTS AND DISCUSSION

A. Influence of Al Lm6, Boron Carbide and Fly Ash Composite on the Coefficient Of Friction

Table 4: Load Vs Coefficient of friction.

Weight percentage of boron carbide and fly ash	Applied load (N)	Coefficient of friction(μ) for different weight percentages		
		3%	6%	9%
3%	15	0.35	0.46	0.52
6%	30	0.5	0.49	0.61
9%	45	0.6	0.65	0.75

The Variation of coefficient of friction of the composite of three different percentages for the applied load shown in figure 14. The coefficient of friction increases for 3% with the increase for the applied load of 15 N and the coefficient of friction increases for 6% decrease for the applied load of 30 N and coefficient of friction increases for 9% increase for the applied load 45 N .The coefficient of friction is high for the composite for 9% when compared to 3% and 6% . The reduction of coefficient of friction is due to the major role played by the creation of boron oxide layer at the contact zone. The boron carbide reacts readily with environment and leads to the formation of boron oxide layer. The creation of boron oxide layer is influenced by the generation of heat. It is observed that value of coefficient of friction reduces for the load 30 N for 3% and 6% and drastically increases.

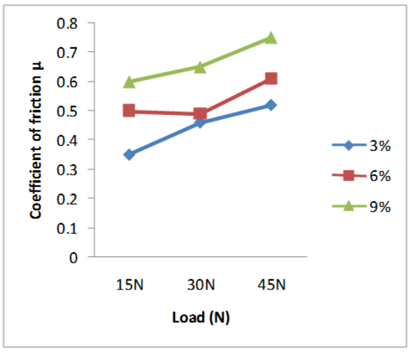

Fig. 14: Load (N) Vs Coefficient of friction.

B. Influence of Al Lm6, Boron Carbide and Fly Ash Composite on Applied Load and Wear Loss

Table 5: Wear loss comparisons.

Weight percentage of boron carbide and fly ash	Wear loss(mg)		
	3%	6%	9%
3%	8	19	24
6%	10	24	26
9%	13	26	28

The Variation of Wear loss of composite reinforced with boron carbide and fly ash with aluminium alloy lm 6 with the normal load is mentioned in the above graph. The wear loss for the composite increases with increase for the applied load (N).The aluminium with boron carbide and fly ash pin of 3% showing the continuous increase of weight loss and then it is drastically increase for the increase in percentage of boron carbide and fly ash.

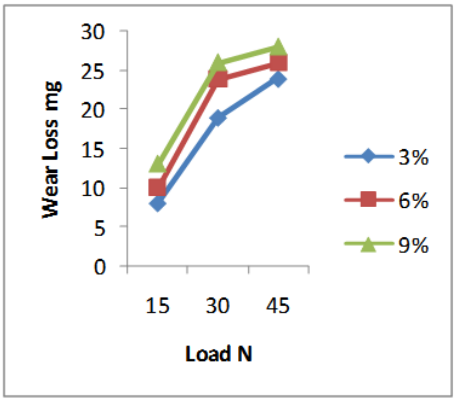

Fig. 15: Load (N) Vs Wear Loss (Mg).

C. Influence of Al Lm6, Boron Carbide And Fly Ash Composite On The Wear Rate:

The Variation of wear rate for the composite reinforced with the boron carbide and fly ash with aluminium alloy LM6 with the normal load is drawn in the above graph. The wear rate for composite specimen decreases with increasing the value of the load. Therefore as the load increases for the composite specimen there will be the reduction in wear rate as well as the percentage of reinforcement increases there will be the decrease in the wear rate for the applied.

Table 6: load vs wear rate.

Weight % of boron carbide and fly ash	Load N	Wear Rate *E-05 mm^2/N		
		3%	6%	9%
3%	2N	0.0628	0.0184	0.0419
6%	3N	0.0209	0.0123	0.0279
9%	5N	0.0125	0.0073	0.0167

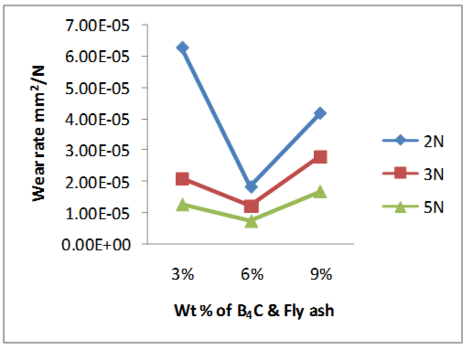

Fig. 16: Wt % of B4C And Fly Ash Vs Wear Rate Mm^2/N.

Conclusion:

Thus the composite specimen was fabricated by stir casting technique with different weight percentages of 3%, 6% and 9% and the different test methods are carried out to study the coefficient of friction, thermal expansion coefficient, weight loss, wear rate and hardness and the results are studied.

The coefficient of friction is increase with increase in the percentage of reinforcement such as boron carbide and fly ash. This hybrid composite shoes that it could not perform better at higher loads and the value of coefficient of friction increases with increase in the value of load (Radhika, N., 2012).

The wear loss for the composite specimen is increase with increase in the percentage of reinforcement such as boron carbide and fly ash.

When compared to the aluminum alloy which has the hardness of about 55 BHN aluminium alloy LM6 reinforced with 3% of boron carbide and fly ash provides hardness value greater than that of aluminium alloy LM6 as when the percentage of reinforcement increases after 3% such as 6% and 9% the hardness value decreases. As the percentage of reinforcement increase to the higher value by using boron carbide and fly ash as a reinforcement there will be the decrease in the value of hardness.

The value of thermal expansion coefficient of aluminium alloy LM6 is 2*E-05/k where when it is reinforced with boron carbide and fly ash it has the value of 2.13E-05 as there is a increase in the value of thermal expansion coefficient for increase in the temperature value as it results in the positive thermal expansion for the change in temperature. The percentage of elongation of the composite specimen aluminium alloy lm6 reinforced with silicon carbide has 5-10% of elongation. But the composite specimen reinforced with boron carbide and fly ash along with aluminium alloy LM6 has percentage of elongation of about 0.75 -1% .So the percentage of elongation is less for the composite reinforced with boron carbide and fly ash.

As the boron carbide is used as a hardening material and to improve mechanical properties also decreasing the wear rate while fly ash is used as a reinforcement along with the boron carbide.

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