Experimental Analysis of Tribological Behavior of Aluminum Metal Matrix Composite Reinforced with Rise Husk Ash (RHA) using Response Surface Methodology

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Abstract- In this work Al-Si alloy (LM6) was reinforced with 15% of flyash and rice husk ash. This experimental analysis shows that Al-Si Alloy based MMC reinforced with fly ash and rice husk ash have a better Tribological behaviour as compared to the Al-Si alloy. The wear test was carried out using pin-on-disk machine with a constant load of 30N with varying sliding speed. The experiments are conducted at both elevated and ambient temperature. Based on the observations of weight loss, wear graphs and C.O.F graphs corresponding observations were drawn. With the help of these experiments it was found that the Al-Si alloy reinforced with waste materials shows a better wear behaviour than the existing Al-Si alloy.
Keywords: Aluminium alloy MMC, reinforcement, tribological properties, wear resistance, waste materials.

1. INTRODUCTION

A composite is a material is made by the combination of two or more materials. This combination takes place at the microscopic level and do not dissolve and blend into each other. The constituent materials possess different properties and work together to give the composite unique properties. One constituent is called reinforcement phase and one in which it embedded is called a matrix phase. The reinforcing material is in the form of fiber, particle or flake. The matrix phase is generally continuous. Traditional engineering materials (steel, aluminum, etc.) Contain impurities that can represent different phases of the same material and fit the broad definition of a composite, but are not considered composites because the elastic modulus or the strength of the impurity phase is nearly identical to that of the pure material.

A. ROLL OF MATRIX IN COMPOSITE

The purpose of the matrix is to bind the reinforcements together by virtue of its cohesive and adhesive characteristics, to transfer load to and between reinforcements, and to protect the reinforcements from environments and handling. The matrix also provides a solid form to the composite, which aids handling during manufacture and is typically required on a finished part. This is particularly necessary in discontinuously reinforced composites, because the reinforcements are not of sufficient length to provide a handle able form. Because the reinforcements are typically stronger and stiffer, the matrix is often the "weak link" in the Composite, from a structural perspective. As a continuous phase, the matrix therefore controls the transverse properties, interlinear strength, and elevated-temperature strength of the composite. However, the matrix allows the strength of the reinforcements to be used to their full potential by providing effective load transfer from external forces to the reinforcement. The matrix holds reinforcing fibers in the proper orientation and position so that they can carry the intended loads and distributes the loads more or less evenly among the reinforcements. Further, the matrix provides a vital inelastic response so that stress concentration are reduced dramatically and internal stresses are redistributed from broken reinforcements.

B. CLASSIFICATION ON COMPOSITE ON THE BASIS OF REINFORCEMENT

Classification refers to the reinforcement form - fiber reinforced composites, laminar composites and particulate composites. Fiber reinforced composites can be further divided into those containing discontinuous or continuous fibers. Fibers are essentially characterized by one very long axis with other two axes either often circular or near circular. Particles have no preferred orientation and so does their shape. Whiskers have a preferred shape but are small both in diameter and length as compared to fibers. Figure shows types of reinforcements in composites.

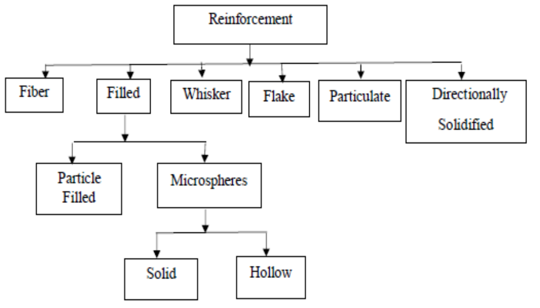

Figure 1: Classification of composite on the basis of reinforcement

C. ALUMINIUM METAL MATRIX COMPOSITE

The development of aluminium matrix composites (AMMCs) is one of the most significant milestones in the history of material. AMMCs were developed to improve the properties of aluminium alloy which can fulfil the requirement of modern engineering products. The composites manufacturing came into existence to form a new material, the properties of which can be tailored according to the requirement by mixing the ductile and tough aluminum matrix with highly wear resistant and strong reinforcements. Ceramics such as SiC, Al2O3, B4C are genrally used as reinforcement.Rrecent investigations have revealed that agro/industrial waste materials such as fly ash, graphite, rice husk ash, bagasse, eggshell, snail shell, coconut shell, bamboo leave ash etc. can be successfully used as a complementary reinforcement in AMMCs.When the aluminium matrix was reinforced with above mentioned reinforcements their strength and tribological properties enhanced as compared to pure aluminium metal and these aluminum matrix composites (AMMCs) combined the metallic properties of matrix alloys (ductility and toughness) with ceramic properties of reinforcements (high strength and high modulus), to form a new material with combination of properties of both matrix and reinforcement.The following properties are typical for Alluminium metal matrix composite (AMMCs).

1. High Strength
2. High stiffness (modulus of elasticity)
3. Good wear resistance
4. Improved high temperature properties
5. Controlled thermal expansion coefficient

D. APPLICATION OF ALUMINUM METAL MATRIX COMPOSITE

AMMCs are used to produce several component aerospace, automotive, marine and nuclear industries. AMMCs were used comprehensively in automobile industries and in specialized areas such as in aircraft engines and marine industry and they were also used as tribological parts in some vehicles. In automotive industry they are used for pistons, cylinders, engine blocks, brakes and power transfer system elements. Some examples of Application off AMMC in automotive application are as follows.

(a) Toyota Motor Co. developed in 1985 a diesel engine piston, in which a discontinuous fibre preform of Al2O3, was infiltrated by squeeze casting into the aluminium matrix.
(b) Aluminium MMC brake drums and rotors have been used in light-weight vehicles such as Lotus Elise, Volkswagen Lupo 3L, Chrysler Plymouth Prowler and General Motors EV-1. Advantage of weight savings (50 - 60 %), higher wear resistance, and higher thermal conductivity was achieved.
(c) Engine blocks of Honda using Al-Al2O3-carbon fiber hybrid composites.
(d) Rear brake drum, drive shaft and engine cradle of General Motors using Al-SiC particle composites.
(e) Piston rings of Toyota using Al-Al2O3 composite.
(f) Connecting rods of Nissan using Al-SiC whiskers composites.

2. LITERATURE REVIEW

B.P. Kumar et al concluded that bamboo leaf ash (BLA) which was extruded from agro waste was used as a particulate reinforcement to produce economical AMMCs by stir casting method.The density of the composites was decreased with the addition of BLA content and conversely, the hardness of the composite was increased in comparison with matrix alloy.

Debashish Dash etal performed experimental analysis which shows that Al-Si Alloy based MMC reinforced with fly ash and rice husk ash have a better tribologicalbehaviour as compared to the Al-Si alloy. The wear test was carried out using pin-on-disk machine with a constant load of 30N with varying sliding speed.

SooryaPrakash Kumarasamy et al worked on characterization of a novel hybrid Aluminum Metal Matrix Composite (AMMC) developed through two-step compocasting method by reinforcing constant amount of flyash cenosphere (10%) and varying quantity of graphite (2%, 4% and 6%) in Al7075 matrix. Results revealed that reinforcement particles have enhanced the tensile strength of Aluminum matrix from 178 N/mm^2 to 213 N/mm^{2}as of the composite is concerned.

Md. HasibulHaqueet al conduct analysis of mechanical properties on metal matrix composite of A-356.2 alloy reinforced with rice husk ash (RHA) particles synthesized by stir casting technique. He found that incorporation of rice husk ash particles in aluminum matrix can lead to the production of low cost aluminum composites with improved hardness and strength.

3. AIM OF PRESENT WORK

(i) Reduction of fuel consumption and vehicle emissions is major challenge in front of automotive industry. Which can achieved by reducing weight of vehicle and frictional losses in engine.
(ii) Standard materials used in engine industry (grey cast iron and steel). These materials are very high mass, and decrease the efficiency.
(iii) The basic requirements on fuel economy and vehicle emissions is very high.
(iv) Unfortunately their tribological properties are not satisfactory, which limits their application in manufacturing the tribomechanical components.

4. METHODOLOGY

A. RISE HUSK ASH (RHA) AS REINFORCEMENT

Rice husk (RH) is an agricultural waste material abundantly available in rice-producing countries. They are the natural sheaths that from on rice grains during their growth. Removed during the refining of rice, these husks have no commercial interest [7]. Globally, approximately 600 million tons of rice paddy is produced each year. On average 20% of the rice paddy is husk, giving an annual total production of 120 million tones. A large quantity of husk, which is known to have a fibrous material with high silica content, is available as waste from rice milling industries.

The treatment of rice husk as a resource for energy production is a departure from the perception that husks present disposal problems. Rice husk is unusually high in ash compared to other biomass fuels – close to 20%. The ash is 92 to 95% silica, highly porous and lightweight, with a very high external surface area. Its absorbent and insulating properties are useful to many research studies. The chemical composition of the rice husk ash varies from sample to sample which may be due to the different geographical conditions, type of paddy, climatic conditions and type of fertilizer used. RHA is one of the best economical, and 41 light-weight reinforcement that contains SiO2, Al2O3 etc. Utilization of Rice Husk Ash (RHA) as reinforcement will not only take care the problems of disposition of waste, but will also bring down the cost of material.
The rise husk was sourced locally from a rice farm house located at mandideep MP India and then processed according to literature. Firstly rice husk was burned in incinerator at 250^o C for 1 hour in order to remove oxide then burned rice husk was heated on muffle furnace at 600^{o}C for 10 hours to remove the carbonaceous materials and other volatiles then obtained RHA particles.

B. STUDY OF TRIBOLOGICAL BEHAVIOR

For the study of tribological study of prepared specimen wear and frictional studies of specimen is done by the help of pin on disc wear testing machine.

C. EXPERIMENTAL DESIGN FOR WEAR STUDY

Experimental design is made by using Design Expert Software. The most popular design in response surface methodology is central composite design (CCD).The various factors and their levels which are used for analysis and construction of design matrix.

Table 1: Factor and their level in CCD experimental design

Parameters	Notation	Units	Levels	
			Min	Max
Sliding Velocity	V	m/s	0.4	2
Sliding Distance	D	m	400	2000
Normal Load	L	N	10	50
Rice Husk Ash	RHA	Wt%	0	20

D. WEAR TESTING

A pin-on-disk wear testing machine was employed to evaluate wear resistance of sample of different composition. Wear tests were conducted at room temperature. AISI 52100 steel disc (60HRC hardness) were employed as the counter face. Wear tests were carried out under varying loads and sliding distance, Sample having diameter of 8 mm and length 24 mm was prepared in order to maintain perfect length to diameter ratio of specimen. Following procedure is followed to do wear test.

(i) First of all sample is polished properly with grit paper 120, 240, 320, and 400 grit paper in order to obtained uniform surface , that the sample(pin) properly mounted over disc.

(ii) Then open the sample holder with the help of screw driver and mount the sample on disc properly ensure that pin is properly mounted on disc as shown in Figure

(iii) Then set the test parameter according to calculation.

(iv) When wear test performed by varying sliding distance time and track radius also calculated and set according to calculation.

(v) Then start the test.

(vi) Worn out sample is cut with the help of hexa blade and wear debris is collected after different test for microstructural analysis of worn out surface.

(vii) After each test disc was cleaned with acetone.

The result in the form of graph between Coefficient of friction, Frictional force and wear rate versus time is obtained and analyzed.

5. CONCLUSION

From the experiment conducted following conclusion have been obtained.

(a) Aluminum metal matrix composite reinforced with Rice husk Ash can be successfully fabricated by powder metallurgy technique.

(b) Composite possess best tribological properties among all the prepared composites.

(c) With increase in weight percentage of Rice husk ash (RHA) in Composite Hardness of composite increases which results in decreasing wear loss.

(d) SEM image revealed that RHA particle are well distributed in Aluminum matrix.

(e) The wear rate of composites decreased with increase in sliding speed, sliding distance and reinforcement wt % and decreased with increase in normal load.

(f) The wear resistance of developed composites was higher than that of cast metal matrix.

This is due to the formation of MML on the worn surface of the composite which played akey role played in controlling the wear properties of the composites.

(g) The ANOVA indicated that normal load is the most influential factor followed by reinforcement wt %, sliding distance and load on the wear rate of composites.

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