Comprehensive Study & Behaviour of Al-6063/Red Mud Metal Matrix Composite

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ABSTRACT

Metal matrix composites (MMCs) possess significantly improved properties including high specific strength; specific modulus, damping capacity and good wear resistance compared to Unreinforced alloys. There has been an increasing interest in composites containing low density and low cost reinforcements. Among various discontinuous dispersoids used, Red Mud is one of the most inexpensive reinforcement available in large quantities as solid waste by-product during bayer process, the principal industrial means of refining bauxite in order to provide alumina as raw material for the electrolysis of aluminium by the Hall–Héroult process. Hence, composites with Red Mud as reinforcement are likely to overcome the cost barrier for wide spread applications in automotive and small engine applications. It is therefore expected that the incorporation of Red Mud particles in aluminium alloy will promote yet another use of this low-cost waste by-product and, at the same time, has the potential for conserving energy intensive aluminium and thereby, reducing the cost of aluminium products. Now a days the particulate reinforced aluminium matrix composite are gaining importance because of their low cost with advantages like isotropic properties and the possibility of secondary processing facilitating fabrication of secondary components. The present investigation has been focused on the utilization of abundantly available industrial waste Red Mud in useful manner by dispersing it into aluminium to produce composites by stir casting method. Tribological behavior of the metal matrix composites was studied by performing dry sliding wear test using a pin-on-disc wear tester. Experiments were conducted based on the plan of experiments generated through Taguchi’s technique. L9 Orthogonal array was selected for analysis of the data. Investigation to find the influence of sliding speed, applied load and sliding distance on wear rate, as well as the coefficient of friction during wearing process was carried out using ANOVA and regression equation for each response were developed for both 5% and 10% Red Mud reinforced Al-6063MMCs. Objective of the model was chosen as “smaller the better” characteristics to analyze the dry sliding wear resistance. Results show that sliding distance has the highest influence followed by load and sliding speed. Finally Scanning Electron Microscope were done on wear surfaces.

INTRODUCTION

Monolithic materials have limitations in achieving good combination of strength, stiffness, toughness and density. To overcome these shortcomings and to meet the ever increasing demand of modern day technology, composites are most promising materials of recent interest. Metal matrix composites (MMCs) possess significantly improved properties including high specific strength; specific modulus, damping capacity and good wear resistance compared to unreinforced alloys. There has been an increasing interest in composites containing low density and low cost reinforcements. Among various discontinuous dispersoids used, Red Mud is one of the most inexpensive and low density reinforcement available in large quantities as solid waste product of Bayer process. Hence, composites with Red Mud as reinforcement are likely to overcome the cost barrier for wide spread applications in automotive and small engine applications. It is therefore expected that the incorporation of red mud particles in aluminium will promote yet another use of this low-cost waste by-product and, at the same time, has the potential for conserving energy intensive aluminium and thereby, reducing the cost of aluminium products.

Now a days the particulate reinforced aluminium matrix composite are gaining importance because of their low cost with advantages like isotropic properties and the possibility of secondary processing facilitating fabrication of secondary components. Cast aluminium matrix particle reinforced composites have higher specific strength, specific modulus and good wear resistance as compared to unreinforced alloys. The particulate composite can be prepared by injecting the reinforcing particles into liquid matrix through liquid metallurgy route by casting. Casting route is preferred as it is less expensive and amenable to mass production. Among the entire liquid state production routes, stir casting is the simplest and cheapest one. The only problem associated with this process is the non uniform distribution ofthe particulate due to poor wet ability and gravity regulated segregation.
Composite

Composite material is a material composed of two or more distinct phases (matrix phase and reinforcing phase) and having bulk properties significantly different from those of any of the constituents. Many of common materials (metals, alloys, doped ceramics and polymers mixed with additives) also have a small amount of dispersed phases in their structures, however they are not considered as composite materials since their properties are similar to those of their base constituents (physical property of steel are temperature, electronic substrates, bicycles, automobiles, golf clubs –
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- resistances and resistance to most radiations. Ceramic reinforcement may be silicon carbide, boron, alumina, silicon nitride, boron carbide, boron nitride etc. whereas Metallic Reinforcement may be tungsten, beryllium etc. MMCs are used for Space Shuttle, commercial airliners, electronic substrates, bicycles, automobiles, golf clubs and a variety of other applications. From a material point of view, when compared to polymer matrix composites, the advantages of MMCs lie in their retention of strength and stiffness at elevated temperature, good abrasion and creep resistance properties. Most MMCs are still in the development stage or the early stages of production and are not so widely established as polymer matrix composites. The biggest disadvantages of MMCs are their high costs of fabrication, which has placed limitations on their actual applications. There are also advantages in some of the physical attributes of MMCs such as no significant moisture absorption properties, non-inflammability, low electrical and thermal conductivities and resistance to most radiations. MMCs have existed for the past 30 years and a wide range of MMCs have been studied.

LITERATURE REVIEW

The literature survey is carried out to study and evaluate the abrasive wear and solid particle erosion (SPE) wear properties of Al-Si alloys and Al MMCs. The various operating parameters viz. impact angle and applied pressure in solid particle erosion wear and normal load, sliding distance, sliding speed, silicon content for abrasive wear are studied. The work of researchers in this respect is been considered. Their conclusions are as follows:

A.T. Alpas and J. Zhang have studied The dry sliding wear behavior of cast aluminium 7% silicon alloys (A356) reinforced with SiC particles was investigated by means of a block-onring (52100 bearing steel) type wear rig. Wear rates of the composites with 10–20 vol. % SiC were measured over a load range of 1–150 N at sliding velocities of 0.16 and 0.8 m s−1. At low loads, corresponding to stresses lower than the particle fracture strength, SiC particles acted as load-bearing elements and their abrasive action on the steel counter face caused transfer of iron-rich layers onto the contact surfaces. In this regime, SiC reinforced composites exhibited wear rates about an order of magnitude lower than those of the unreinforced alloys in which wear occurred by subsurface crack nucleation, around the silicon particles, and growth.

N. Axén ,M. Hutchings and S. Jacobson studied and presented a model for the sliding friction of multiphase materials in abrasion. Different load distribution modes are used with Amontons’ first law of friction to derive both the friction force and the coefficient of friction as functions of the area fractions of the phases, their individual coefficients of friction and their wear resistance. It is shown that the coefficient of friction of a multiphase material should depend on the load distribution mode and that the upper and lower limits for the coefficient of friction expected from composites or multiphase materials can be identified. For most pressure distribution modes, the friction depends on the wear resistance of the phases.

Vishal Sharma in his investigation, synthesized Al-4.5wt%Cu/Zircon Sand/SiC hybrid composite by stir casting route by controlling various casting parameters. The as-cast samples were observed under optical and scanning electron microscope. Micro structural observations of the as-cast hybrid composite, shows uniform distribution of reinforcement particles and also good interfacial bonding between the particles and the matrix. Micro hardness tester is employed to evaluate the interfacial bonding between the particles and the matrix by indenting the micro hardness indenter on the particle with the varying load (100 gm, 200 gm, and 300 gm) and time (10 sec, 15 sec, 20 sec and 25 sec). It has been concluded that by the variation in hardness at constant load varying time or at constant time varying load, the bond strength can be compared. Shailove Kumar Studied the age hardening behaviour of Aluminium alloy (6351) - 9%wt SiC composite produced by the stir casting technique. Water and Brine solution has been used as the quenching media. Thermal ageing has been done at different temperature, time and quenching media. Micro hardness and wear tests were performed on the samples
obtained from the stir casting process. The results of ageing demonstrate that the micro hardness of the composite depend on the quenching medium in which they are heat treated and peak hardness depends on quenching media and ageing time durations. X-ray Diffraction was performed to know the presence of the phases of reinforced material. Optical micrograph was taken to know the distribution of SiC particles in aluminium alloy.

Sanjeev Kumar investigated the effects of thermal cycling on cast aluminium composites reinforced with silicon carbide and fly ash particles. During this investigation, dry fly ash was used with aluminium reinforced with SiC and a composite was prepared using Liquid 30 metal stir casting route with the reducing quantity of SiC. During the research, thermal cycling was carried out on the samples prepared and effects on samples before and after thermal cycling were observed.

S. L. Coleman investigated the corrosion characteristics, in 3.5 wt% NaCl solution, of aluminium alloy composites containing a range of reinforcements using potentiostatic measurements and simple immersion tests. Complementary microstructural studies carried out on corroded surfaces and sections through corroded material have identified a number of preferential corrosion sites; these include the fiber/matrix interface, especially where it contains chemical reaction products resulting from composite fabrication, as well as second phases and pores in the metal matrix. The effect on corrosion behaviour of the different reinforcements, with particular reference to their chemistry and geometry, is discussed, as is the influence of composite manufacturing route.

METHODOLOGY

Study of literature reveals that behavior of metal matrix composite is very complex and theoretical examination of the process is very difficult. Regarding empirical results, much research work is required with combination of different metal matrix and reinforcement. Also, most of the research work is with Al (6061 series) metal matrix. Much investigation is needed regarding other types of metal matrix like Al (6063 series). Also nobody reported regarding resistivity and conductivity and wear behavior of Al6063 metal matrix with fly ash/red mud composite. There is a literature gap regarding investigation of behavior of Al6063 metal matrix composite. In the present study, Al-6063/Red Mud metal matrix composite is developed for two different compositions by using stir casting process. The wear and frictional properties of the metal matrix composites are studied by performing dry sliding wear test using a pin-on-disc wear tester. Experiments are conducted based on the plan of experiments generated through Taguchi’s technique. A L9 Orthogonal array is selected for analysis of the data. Investigation to find the influence of applied load, sliding speed and sliding distance on wear rate, as well as the coefficient of friction during wearing process is carried out using ANOVA. The process for the development of Al-6063/Red Mud metal matrix composite is described. And finally the tribological experimentation is presented.

Fig 1: Flow Chart showing steps involved in stir casting
RESULTS AND DISCUSSION

Microstructure of Aluminium Alloy and Composites before Wear Test

The casting procedure was examined under the optical microscope to determine the cast structure. For the sample preparation, first of all sample were cut down into small cuboids shapes then the sample grinded on different grit size paper sequentially by 100, 220, 320, 400, 600 and 1000. After grinding, the samples were polished by alumina paste and etched with Keller’s solution. The samples were visualized and it is observed that there is a strong interfacial bonding between particles. Red mud particles are uniformly distributed throughout the matrix as shown in optical micrography.

![Figure 2: Optical micrographs of Base Alloy at X500](image)

Scanning Electron Microscopy before Wear Test Figure 3 shows the scanning electron micrographs of the hybrid composite. It is observed that the particles are uniformly distributed throughout the matrix for the cast hybrid composite.

![Figure 3: SEM of Al-5% Red Mud blank surface](image)
Wear Test Result

The aim of the experimental plan is to find the important factors and combination of factors influencing the wear process to achieve the minimum wear rate and coefficient of friction. The experiments were developed based on an orthogonal array, with the aim of relating the influence of sliding speed, applied load and sliding distance. These design parameters are distinct and intrinsic feature of the process that influence and determine the composite performance. Taguchi recommends analyzing the S/N ratio using conceptual approach that involves graphing the effects and visually identifying the significant factors.

The results for various combinations of parameters were obtained by conducting the experiment as per the orthogonal array. The measured results were analyzed using the commercial software MINITAB 15 specifically used for design of experiment applications. The experimental results average of two repetitions for wear rate and coefficient of friction. To measure the quality characteristics, the experimental values are transformed into signal to noise ratio. The influence of control parameters such as load, sliding speed, and sliding distance on wear rate and coefficient of friction has been analyzed using signal to noise response table. The ranking of process parameters using signal to noise ratios obtained for different parameter levels for wear rate and coefficient of friction are given in respectively for 5% & 10% reinforced Red Mud MMCs.

CONCLUSIONS

The following conclusions can be drawn from the present investigation:

- From the study it is concluded that we can use Red Mud for the production of composites and can turn industrial waste into industrial wealth. This can also solve the problem of storage and disposal of Red Mud.
- AA 6063 alloy matrix composites reinforced with Red Mud particles can be successfully synthesized by the stir casting method.
- For synthesizing of hybrid composite by stir casting process, stirrer design and position, stirring speed and time, melting and pouring temperature, particle-preheating temperature, particle incorporation rate, mould type and size, and reinforcement particle size and amount are the important process parameters.
- Microstructural observations show that the Red Mud particles are uniformly distributed in the Al6063 alloy matrix and good interfacial bonding between reinforcing particles and matrix.
- XRD results showed the presence of Red Mud particles in alloy matrix.
- Sliding distance (62.5%) has the highest influence on wear rate followed by sliding speed(37.5%) and applied load (1.25%) and for coefficient of friction, the contribution of applied load is 87.2%, sliding distance is 13.4% for Al – 6063/5% Red Mud metal matrix composites.
- Applied load (57.2%) has the highest influence on wear rate followed by sliding distance (7.1%) and sliding speed (7.1%) and for coefficient of friction, the contribution of applied load is 87.2%, sliding distance is 9.7% for Al – 6063/10% Red Mud metal matrix composites.
- Increasing incorporation of Red Mud (5% & 10%) increases the wear resistance of composites by forming a protective layer between pin & counter face.
- From the above conclusion we predict that sliding distance & applied load have the highest influence on wear rate in both composites.
- Similarly applied load is only parameter which largely influences the coefficient of friction in both composites.
- Regression equation generated for the (5% & 10% Red Mud MMCs) present model was used to predict the wear rate & coefficient of friction of Al – 6063/ (5% & 10%) Red Mud MMCs for intermediate conditions with reasonable accuracy.

REFERENCES


