International Journal on Applications in Mechanical and Production Engineering
Volume 2: Issue 5: May 2016, pp 1-5. www.aetsjournal.com ISSN (Online) : 2395 -3500

Application of RSM and CCD to Predict the Wear of Aluminium and Red Mud MMC

M.Thangasadayan , G.Selvaraj

Abstract — Red mud emerges as the major Waste material during production of aluminum from bauxite by the Bayer's process. Silica sand Red mud Waste is the most inexpensive reinforcement available in the large amount around Villupuram district, Tamilnadu. Metal matrix composites have been playing major role in recent times as it has got significant properties. Aluminum-Red mud metal matrix composites have found application of various Mechanical, Aeronautical, Marine and locomotive engineering where adhesive wear (or dry sliding wear) is a predominant process. Materials possessing high wear resistance (under dry sliding conditions) are associated with a tribological behavior on the wearing surface. Most of the researchers already discussed about the development and characteristics of this type of MMC that were done. Nowadays modeling and optimization of parameters influence to the wear so far resistance under dry sliding conditions researches are going on. So objective is on prediction of wear parameter like applied load speed and time on the dry sliding wear of MMC using pin and disc apparatus and develop the mathematical model and find the optimize the minimum wear by using response surface methodology technique. A plan of experiments will be developed based on central composite design (CCD) to obtain data in a controlled way for different speed, under different loads and different timings. Experiments will be conducted under laboratory condition to record the wear resistance values of the aluminum red mud composite under different composition of process parameter conditions in pure sliding mode on a pin on disc machine. To developing the mathematical models and optimize the wears at minimum level of using DOE++ software. Finally the direct and interaction effect of process parameters will be discussed with the help of graphical plots and the validity of the model and optimization will be checked by prediction results obtained from RSM comparing with experimental results.

Keywords: Aluminum alloy, Red mud CCD, Wear, RSM Response Surface Methodology

I. INTRODUCTION

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 similar to those of pure iron). A composite material is a material composed of two or more constituents. The constituents are combined at a microscopic level and are not soluble in each other. Generally, a composite material is composed of reinforcement (fibers, particles/ particulates, flakes, and/or fillers) embedded in a matrix (metals, polymers) [1]. The increased volume has resulted in an expected reduction in costs. High performance FRP can now be found in such diverse applications as composite armoring designed to resist explosive impacts, fuel cylinders for natural gas vehicles, windmill blades, industrial drive shafts, support beams of highway bridges and even paper making rollers [2]. The composite material can be designed considering the structural aspects. The design of a structural component using composites involves both material and structural design. Composite properties (e.g. stiffness, thermal expansion etc.) can be varied continuously over a broad range of values under the control of the designer [3]. The increased volume has resulted in an expected reduction in costs. High performance FRP can now be found in such diverse applications as composite armoring designed to resist explosive impacts, fuel cylinders for natural gas vehicles, windmill blades, industrial drive shafts, support beams of highway bridges and even paper making rollers [4]. A fiber is characterized by its length being much greater compared to its cross-sectional dimensions. The dimensions of the reinforcement determine its capability of contributing its properties to the composite. Fibers are very effective in improving the fracture resistance of the matrix since a reinforcement having a long dimension discourages the growth of incipient cracks normal to the reinforcement that might otherwise lead to failure, particularly with brittle matrices [5]. Fiber reinforced composite material consist of fibe of high strength and modulus embedded in or bonded to a matrix with distinct interfaces between them. In this form, both fiber and matrix retain their physical and chemical identities, yet they produce a combination of properties that cannot be achieved with either of the constituents acting alone [6]. The woven and continuous fiber styles are typically available in a variety of forms, being pre-impregnated with the given matrix (resin), dry, uni-directional tapes of various widths, plain weave, hardness satins, braided, and stitched [7]. the term metal matrix composites is often equated with the term light metal matrix composites (MMCs). The progress development of light metal matrix composites

M.Thangasadayan , PG Scholar , Department of Mechanical Engineering , Selvam College of Technology , Tamilnadu.
G.Selvaraj , Head of the Deparment , Department of Mechanical Engineering , Selvam College of Technology , Tamilnadu.

has been achieved in recent decades, so that they could be introduced into the most important applications [8].

II. MATERIAL SELECTION

A. RED MUD

Red mud is the caustic insoluble waste residue generated by alumina production from bauxite by the Bayer's process at an estimated annual rate of 66 and 1.7 million tons, respectively, in the World and India. It is estimated that two tons of alumina used to produce one ton of Aluminum and 58% of alumina and 42% of red mud come out from one ton of bauxite approximately. Under normal conditions, when one ton of alumina is produced nearly a ton of red mud is generated as a waste. Different avenues of red mud utilization are more or 19 less known but none of them have so far proved to be economically viable or commercially feasible [9]. However, a survey of literature on utilization of red mud published so far [10], it is revealed that use of red mud is restricted only for recovery of some metal values like Titanium, Vanadium and Zinc; making of ceramics etc. It has also been used for making cement, bricks, pigments and glazed sewer pipes etc. Research and development work on red mud utilization that are under process in India are shown in table 1. Going through the available information on the utilization of red mud, it is seen that use of red mud as reinforcement material for preparation of MMC has not been explored.

Fig.1 Red Mud

III. ALUMINUM MATRIX

A. Need for the reinforcement

To obtain Optimum performance from composite materials there is an advantage to selecting the shape and size of the reinforcement material to fit the application. It is apparent that different material types and shapes will have advantages in different matrices There are so many researchers have worked out separately to reinforce SiC, Al2O3 (i.e. carbides, Nitrides and oxides) TiC, Boron and Graphite in to the Aluminum matrix to achieve different properties. There are various researches and development works are going on the red mud utilization in India which is shown in Table.

Table.1 Research and development work on red mud utilization in India

Madras Aluminum Company	Red mud as a component in cement
Central building research institute	Production bricks with red mud and clay with equal proportions
CECRI, Karaikudi	Materials for primers
RRL, Bhubaneswar	Recovery of vanadium, chromium &alumna
NEITCO	Manufacture of red mud corrugated sheets.
RRL, Bhopal	Utilization of red mud pvc and lab scale product Designed as red mud plastic (RMP).
Central glass and ceramic research institute	Conversion of red mud to ceramics.
NML, Jamshedpur &RRL, BBSR	Recovery of V2 O5 and Al 2O 3.
Metallurgical Dept. B.H.U.	Development of bricks, recovery of titanium and Ferro titanium
Rajasthan Financial Corporation	Manufacture of pipes and corrugated sheets.
NALCO, Ltd	Filler to pvc sheets, pipes and pigment as per ISI norm, patents file.
Lotus roofing Pvt Ltd.	Corrugated sheets.
Dept.of Metallurgy and Material	Conversion of red mud into Ferro alloy and wear

Out of the available manufacturing procedures we have adopted the usual stir casting technique to prepare the MMC. Different Volume fraction of red mud has been mixed with the matrix material.

B. MACHINE SELECTION

CNC is computerized technology by controlling the relative movements between the tool and the work piece geometrical shapes are machined. Control of these relative movements through coded letters numbers is known as Numerical Control of machine tools.

IV. ALUMINUM OXIDE, AL2O3 CERAMIC PROPERTIES

Alumina is one of the most cost effective and widely used materials in the family of engineering ceramics. The raw materials from which this high performance technical grade ceramic is made are readily available and reasonably priced, resulting in good value for the cost in fabricated alumina shapes. With an excellent combination of properties and an attractive price, it is no surprise that fine grain technical grade alumina has a very wide range of applications. To ensure the security of the cloud stored contents from them who are meant to be third party servers, cryptographic based encryption is introduced. This will allow users to store the encrypted contents in the cloud server instead of storing the plain texts directly. Thu the security for the cloud data owners is ensured.

Stir casting:

Stir Casting is a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring in the stir casting process, the alloy is melted at a controlled temperature and the desired quantity of fly ash is added to the molten aluminum alloy. The molten alloy is stirred continuously to create a vortex to force the slightly lighter particles into the melt. Stirring continues to disperse the fly ash particles as uniformly as possible in a short time. The matrix is then transferred into a preheated and precoated transfer ladle. The material is stirred again and then poured into preheated permanent molds. It is then cooled, cut to shape, and surface cleaned.

V.STIR CASTING VARIABLE PARAMETERS

A key challenge in the processing of composites is to homogeneously distribute the reinforcement phases to achieve a defect-free microstructure. Based on the shape, the reinforcing phases in the composite can be either particles or fibers.

The relatively low material cost and suitability for automatic processing has made the particulate-reinforced composite preferable to the fiber-reinforced composite for automotive applications. Following are the process parameters of stir casting route:

a) Speed of rotation For successful production of casting, the control of speed is very important. Rotational speed also influences the structure; increase of speed promotes refinement and very low speed results in instability of the liquid mass. It is logical to use the highest speed to avoid tearing.

b) Stirring speed Stirring speed is one of the most important process parameters as wet ability is promoted by stirring i.e. bonding between matrix & reinforcement. The flow pattern of the molten metal is directly controlled by the stirring speed. The speed range between 300 and 600 rpm is optimum. As solidifying rate is faster it will increase the percentage of wet ability.

VI. GAS PRESSURE INFILTRATION

Gas Pressure Infiltration is a forced infiltration method of liquid phase fabrication of Metal Matrix Composites, using a pressurized gas for applying pressure on the molten metal and forcing it to penetrate into a preformed dispersed phase. Gas Pressure Infiltration method is used for manufacturing large composite parts.

The method allows using non-coated fibers due to short contact time of the fibers with the hot metal. In contrast to the methods using mechanical force, Gas Pressure Infiltration results in low damage of the fibers.

VII. EXPERIMENTAL PROCEDUREPRESSURE DIE INFILTRATION

Pressure Die Infiltration is a forced infiltration method of liquid phase fabrication of Metal Matrix Composites, using a Die casting technology, when a preformed dispersed phase (particles, fibers) is placed into a die (mould) which is then filled with a molten metal entering the die through a spur and penetrating into the pre form under the pressure of a movable piston (plunger).

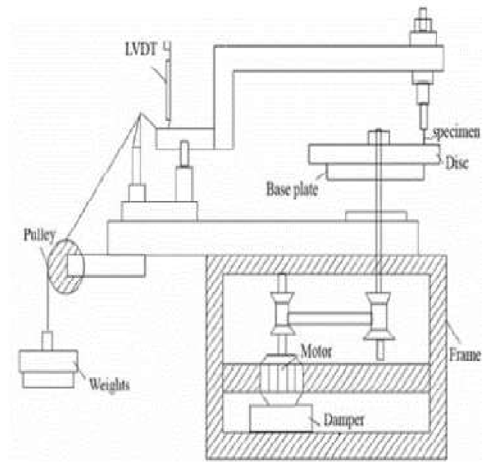

Fig. 3: Schematic Diagram of Pin on Disc Test Rig.

VIII. CASTING EXPERIMENTAL PROCEDURE

- Aluminum alloy (6061) was first superheated to its melting point in graphite crucible.
- Powder Sic preheated in the different temperatures and then was wrapped into aluminum foils and added to the molten metal in the two different compositions like 1%

Table.2

Method	Range of shape and size	Range of vol. fraction	Damage to reinforcement	Cost
Stir casting	wide range of shapes; Larger size; up to 500 kg	Up to 0.3	No damage	Least expansive
Squeeze casting	limited by pre form shape Up to 2cm height	Up to 0.5	severe damage	Moderate expansive
Powder metallurgy	wide range; restricted size		reinforcement fracture	Expansive
Spray casting	Limited shape, large shape	0.3-0.7		Expansive

- Stirring was carried out at constant rate of 420 rpm for 14min.
- Finally, specimens are fabricated in good conditions were prepared for subsequent tribological analysis.

IX. CORROSION TEST

Thermal corrosion is a mechanism of corrosion that takes place in gas turbines, diesel engines, furnaces or other machinery coming in contact with hot gas containing certain contaminants. Fuel sometimes contains vanadium compounds or sulfates which can form compounds during combustion having a low melting point.

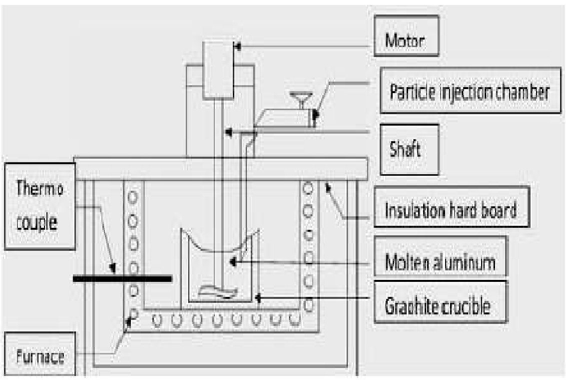

Fig. 4. Stir casting Experimental set up

X. WEAR TESTING

The dry sliding wear behavior of the Al-Sic + various leaf ashes composite at room temperature, a pin-on-disc wear testing machine was used as shown in fig In this method two different sets (as-casted in 1 and 1.5% composition) of pins were fabricated from composites viz. The pin dimension was 8 mm in diameter and 30 mm in length. The counterpart disc with 70 mm in outside diameter and 10 mm in thickness was fabricated using high carbon high chromium steel. The each test pin was loaded against the disc with a dead weight. The tests were carried out at the room temperature with the fixed sliding wear parameters, namely, the load as 9.8 N, the sliding speed as m/s for 20 min.

Fig. 5. General corrosion testing

XI. FATIGUE TEST

A specified mean load (which may be zero) and an alternating load are applied to a specimen and the number of cycles required to produce failure (fatigue life) is recorded. Depending on amplitude of the mean and cyclic load, net stress in the specimen may be in one direction through the loading cycle, or may reverse direction. Data from fatigue testing often are presented in an S-N diagram which is a plot of the number of cycles required to cause failure in a specimen against the amplitude of the cyclical stress developed. The cyclical stress represented may be stress amplitude, maximum stress or minimum stress. Each curve in the diagram represents a constant mean stress. Most fatigue tests are conducted in flexure, rotating beam, or vibratory type machines.

XII. IMPACT TEST

Impact strength indicates the toughness of the material. Toughness can be defined as ability of a material to absorb energy exerted by external force before it undergoes fracture. Most of mechanical properties and product life, product safety and liability are dependent on impact strength.

The impact tests are carried out on specimens using an Impact testing machine of izod type at room temperature. And the specimens are prepared according to ASTM standard E23. The size of the specimen for the impact test was 10mm x 10mm x 55mm with a rectangle notch size of 2mm with an included angle of 120^0

Fig. 6.Impact Testing Machine

XIII. CONCLUSION

This review presents the views, different experimental technics, results obtained and conclusions made over theyears by numerous investigators in the field of particle reinforced Al-7075MMCs. A considerable amount of interest in Al-7075 MMCs evinced by researchers from academics and industries has helped in conduction of various studies and has enriched our knowledge about the physical properties, mechanical properties and tribological characteristics. Several techniques are followed by researchers for the processing of particulate reinforced MMCs. The hardness of the composites was reviewed and on conclusion, it is discovered that as the reinforcement contents increased in the matrix material, the hardness of the composites also increased. Further, the tests conducted to determine the same indicated the (Vickers and Brinell's hardness) increased hardness with increased reinforcement contents when compare with the base matrix. The mechanical properties were reviewed with respect to strength. It is evident that the structures and properties of the reinforcements control the mechanical properties of the composites.

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