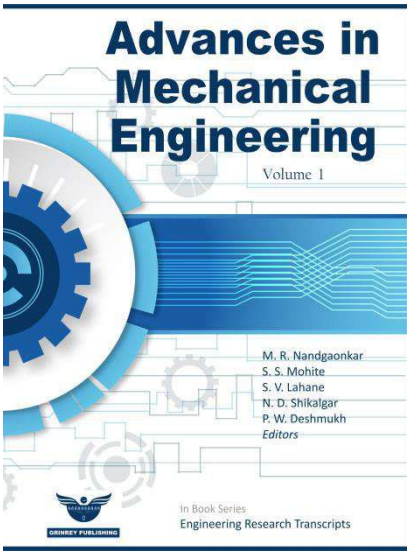

Mechanical, Tribological, Thermal Properties of Aluminium – 7075 Reinforced with Red Mud/Fly Ash Metal Matrix Composite: A review

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Abstract

The term Metal Matrix Composite (MMC) refers to composites with metallic matrix having reinforcing constituent mostly in the form of ceramic. Reinforcement is normally nonmetallic. Aluminium alloy matrix (AMCs) composite and reinforcements by ceramic find widely applications in industries like aerospace and defense, automotive sector as it possesses high ratio of strength to weight, impact strength, stiffness, resistance to wear etc as compared with the steel alloy-based counterparts. The major problem associated with reinforcement of MMC is the cost of reinforcement. Fly ash can be explored as reinforcement as it has a lower density, and offer better physical properties and it is available at lesser cost as compared to that of other reinforcements used presently. Use of fly ash into aluminium alloy will potentially reduce the pollution of environment. Products can also be manufactured at low cost with better properties. Red mud is another cheap, waste material obtained during Bayer's process to extract alumina from bauxite. Oxidized iron which is present in to the extent of 60 % is responsible for the red colour of the red mud. Red mud contains majorly iron oxide, aluminium titanium and silica in remaining percent. Red mud also contains other constituents as minor content. In order to improve the tribological, thermal and mechanical properties of Aluminium – 7075 reinforced by red mud/fly ash metal matrix composite a detailed review is presented in this paper. The research regarding the thermal, mechanical and tribological properties of base metal Aluminium – 7075 composite using reinforcement as fly ash and red mud manufacturing stir casting process needs to be undertaken as per the gap identified.

1. Introduction

The term Metal Matrix Composite (MMC) refers to composites with metallic matrix having reinforcing constituent mostly in the form of ceramic [1]. Reinforcement is normally non metallic. Aluminium alloy matrix (AMCs) composite and reinforcements by ceramic find widely applications in industries like aerospace and defense, automotive sector as it possesses high ratio of strength to weight, impact strength, stiffness, resistance to wear etc as compared with the steel alloy-based counterparts. Classification of MMC based on the form of reinforcement as particles, short fibres or long aligned fibres. Following are some salient features of the MMCs based on type of particulates. [2]

Particulate MMCs

Generally particulates are added to the molten matrix in their pure state. For structural applications reinforcement of particles with a diameter of about 10-20µm is used and 10-30% of the volume of the material is formed by the particles. The MMCs containing reinforcements outside of these ranges (especially finer particles, higher percentage of particle contents) have been studied and are available commercially.[2]

Matrix and Reinforcement Materials

The behaviour of MMCs under different service conditions is governed by the type and nature of the matrix and the reinforcement systems. Because, whenever a composite is subjected to any loading the load is first applied on the matrix and then the force is transferred from the weaker zone of matrix to the stiffer zone of reinforcement through the matrix/reinforcement interface. Hence, a judicious selection of not only the appropriate combination of the two is important, but making use of the correct size and/or proportion of the same, the primary manufacturing route, and application of any secondary process to shape the final parts is equally important, if not more [3,4].

Fly ash as a particle Reinforcement

Fly ash can be explored as reinforcement as it has a lower density, and offer better physical properties and it is available at lesser cost as compared to that of other reinforcements used presently. Use of fly ash into aluminium alloy will potentially reduce the pollution of environment. Products can also be manufactured at low cost with better properties. [4]

Red mud as a particle Reinforcement

Red mud is another cheap, waste material obtained during Bayer's process to extract alumina from bauxite. Oxidized iron which is present in to the extent of 60 % is responsible for the red colour of the red mud. Red mud contains majorly iron oxide, aluminium titanium and silica in remaining percent. Red mud also contains other constituents as minor content. [5].

2. Literature Survey

The composites are engineered by combination of at least two or more than two different materials which can lead to achieve tailor-made properties by a systematic way of combination of various constituents. The conventional materials, termed as 'monolithic' material have limitations of achieving combination of optimum levels of physical and mechanical properties. Metal Matrix Composites offer properties superior to those of nonmetallic materials by combining the advantages of matrix materials and reinforcement materials. A lot of research has been done in MMC. The area of research has many aspects like manufacturing of MMC's and testing their mechanical properties and comparing with conventional alloys by systematically changing the quantity of reinforcements used in various alloys. Many experiments were carried out on specimen with changing the reinforcement proportion. Manufacturing of MMC has again different methods like stir casting, centrifugal casting, powder metallurgy, forging, pressurized casting etc. focus of research may be physical, mechanical, thermal properties. Aluminium finds wide applications in automotive industry, aerospace and architectural applications etc due to its favourable important properties such as high strength to weight ratio, ease in machining, ductility, durability and malleability. Aluminium is easily and abundantly available. Estimated by weight, around 8% of the solid surface of the earth is by Aluminium. Aluminium metal matrix will replace many conventional metals in future.

Following papers are the representation that focused their attention on reinforcement of fly ash and red mud.

Kala H, Merb KKS, Kumar S [6] reviewed that the particle reinforcements such as silicon carbide, alumina, fly ash, graphite etc . These particulates can be easily incorporated in the stir casting method which is widely used and cheaply available. Adding alumina to aluminum as a reinforcement shown increase in the tribological properties and mechanical properties. Reinforcement like coconut ash, fly ash resulted in improving the yield and tensile strength. Machinability of aluminium is seen to be improved due to the Self-lubricating property of graphite.

Shivananda Murthy [7] worked on improving the thermal and Mechanical properties of hybrid composites AA7075 using TiO2 and Fly ash manufactured using hot forging. Authors used stir casting technique and hot forging to fabricate AA7075 matrix-based hybrid composites. They used TiO2 and fly ash as reinforcements. In these hybrid composites, fly ash content was maintained as 3% of weight and weight percentage of TiO2 was varied in the range of 2.5 to 10. Both, fly ash and TiO2 reinforcements in matrix of AA7075 have shown homogenous dispersion by SEM images. mechanical properties of hybrid composites were studied using compression test. Due to the incorporation of multiple reinforcements, compressive strength of the hybrid composites was found to increase. The further increase in the strength with increase of TiO2 particles by weight fraction was seen. The coefficient of thermal expansion measured with a high precision thermo-mechanical analyzer and was found to be between 50 and 250 °C. In these hybrid composites, decrease in thermal coefficient was observed and authors attributed it to the reinforcement of base material using TiO2 and fly ash.

Kanth UR, Rao PS, Krishna MP [8] conducted a study on aluminium-zinc alloy which was reinforced using silicon carbide (SiC) and fly ash to investigated mechanical behaviour. During the study, weight percentages of fly ash and SiC was varied from 0 -10. Composite was prepared using 53 µm particle size. The composites prepared were characterized using Electron back scattered diffraction(EBSD), optical microscope, scanning electron microscope (SEM). Trials to evaluate tensile testing were conducted on UTM. It was revealed from EBSD analysis that the grain size is refined. In the microstructural studies, fly ash and SiC particulates are seen to be distributed uniformly throughout the base metal matrix. Hardness was improved due to inclusion of fly ash particles. Improvement in tensile strength was observed due to addition of SiC particles.

Reddy [9] experimented with reinforcements as fly ash particulates and E-glass short fibers to formed a novel class of hybrid composite Al 7075. Wear resistance, tensile strength and hardness of the novel composite developed was evaluated and validated. Reinforcements resulted the properties to improve significantly of hybrid composite. Compared to the cast composites, enhancement in the properties of heat-treated composites was seen. Artificial Neural Network modelling in MATLAB was used for validation of the results of experimentation. The results indicated the accuracy of experimentation. During this validation, an error of 10% is considered in training of model, its testing and validation.

Canute X, Majumder MC [10] attempted producing hybrid composites using a proportion of % boron carbide powder, 4% of fly ash as a reinforcement to aluminium A356 alloy using stir casting method High-temperature tribological behaviour was studied using Pin heating setup for aluminium A356 alloy with boron carbide and fly ash. Particles of Fly ash, reinforced as a secondary material due to the better properties. Mechanical property evaluation was done using tensile test, micro hardness test. Effect of reinforcement was evaluated using microstructure study. Of the hybrid composites developed, wear rate was evaluated considering load, sliding velocity and temperature. The test were conducted and it was seen that mechanical properties were improved and the particle distribution in the matrix was seen homogeneous. The ductility was reduced however compression strength of developed hybrid composite was increased notably. Critical investigation revealed that the highest significance is of load followed by temperature at contact and surface sliding velocity. The wear rate increased with increasing applied load and temperature however, a wear rate reduced with as sliding velocity increased. Composites such produced may be implemented for typical automobile components demanding high resistance to wear and temperature.

Mali A, Kherde S et al [11] reviewed Aluminum 6061 as matrix and reinforcement material as B4C and fly ash in order to develop Hybrid composite material. They varied weight percentages of reinforcement as 3% to 9% and the Hybrid composite was manufactured using stir casting method. Tensile test, impact test, compression test, wear test and hardness test were conducted in order to evaluate the mechanical porperties of the hybrid composite.

Increase of particles reinforcement increased the tensile strength of the MMC. The ductility of the base metal , on other hand, suffers and gradually reduces due the incorporation of hard reinforcement particles. A considerable increase of 15.33% in tensile strength (15.33%) was observed by adding reinforcement particulate as 7.5 weight percentage compared to a weight percentage of 5 and 2.5. Increasing the percentage of particle reinforcement resulted in an increase of the hardness of newly developed metal matrix composite which is under consideration. Adding reinforcements of 7.5 weight percentage, recorded the highest hardness of 61BHN. Increasing the weight percentage of reinforcement resulted in decrease in specific wear. As per the friction laws, at higher load of 60 N, the specimen wear rate was high when compared to 20N and 40 N load. At speed of 200, 400 and 600 rpm. Wear rate compared with base alloy was recorded to be less.

Prasad N [12] studied that the red mud, which is a process generated waste during extraction from alumina plant may be incorporated as a reinforcement material in production of MMC component in aluminium matrix suitable for resisting wear prone environment. Developed material presents a promising alternative to the components involving aluminium as a base metal. Estimated saving of around 15 percent of matrix material may be achieved. Red mud particles observed to have a good dispersibility in aluminium matrix resulting in improvement of the hardness. Improved hardness enhances the wear resistance of MMC. The specific wear rate of the composite under study decreased with increasing reinforcement volume fraction when it attains a minimum value between 15 to 20% and then after it again increases. In the work presented, wear co-efficient has shown a decreasing tendency with increasing particles volume. It strongly confirms reinforcement of red mud can significantly improves the resistance offered by aluminium based composite to wear.

Sreenivasrao KV et al [13] used average 90µm size of Red Mud Particle (RMP) as a reinforcement in aluminum 8011 alloy. To reinforce the RMP with the matrix, stir casting method process was employed. Optical microscope was used for Metallographic studies. It was revealed that the reinforcement was fairly distributed in matrix material. An increase by 52% in the hardness of the matrix was seen due to with the addition of RMP however a loss of ductility was reported. With an addition of 14% by weight of RMP, Ultimate tensile strength recorded as 117.28 MPa which is higher. It follows gradual decrease with further RMP addition as a reinforcement. Study suggested to use percentage weight volume as 14 of red mud particles in order to obtain better performance.

Nimbalkar SR, Vijay M [14] et al reviewed a significant research on Aluminium7075 MMC's (Metal matrix composites). Reinforcing various particles in ceramic material, applying heat treatment, fabrication processes, controlling process parameters which improves properties of composites are studied in detail. Aluminium 7075 MMC's using reinforcement as ceramics such as Al2O3, TiC, TiB2, TiO2,SiC, B4C, E-glass fibers, Fly ash, Carbon nanoparticals , Graphite power, Red mud using alone and with other reinforcements using Al7075 Hybrid MMCs are studied in depth. Al7075 MMCs show several benefits over single material including strength, strength to weight ratio, resistance to corrosion, wear resistance, improvements in thermal properties.

Pradeep R et al [15] investigated reinforcement of SiC and red mud in aluminium alloy 7075 omposite for improving mechanical properties. The study was undertaken to evaluate mechanical properties of Al with Red Mud and SiC MMC of Aluminium 7075. The weight percentage of SiC, Al7075 and Red Mud particles was varied using stir casting technique. Experimental results revealed that the MMC with reinforcement particles such as SiC and Red mud shows improvement in mechanical properties.

Vinitha et al in [5] worked on evaluating mechanical properties of reinforced Al 7075 Alloy with Redmud , SiC and Flyash, as a reinforcement in a Metal Matrix Composite. Stir Casting method was used to fabricate the MMC. The result obtained for newly developed MMC over MMC with reinforcement SiC and Flyash has higher tensile strength. The impact strength was found to be increasing. Impact strength varies inversely with increase in content of Fly ash and red mud. Wear resistance offered by the MMC proposed is

higher by maintaining constant percentages of weight of SiC and Fly ash. It was found to be decreasing by increasing the weight percentage of Fly ash. Resistance to wear was increasing with increase in content of red mud.

Joshi VP et al [16] used Red Mud as the reinforcement material and Al 7075 as the metal matrix. The chilling effect was incorporated using liquid nitrogen as a chilling agent at -195°C to develop the Metal Matrix Composite. Matrix Material Al 7075 was heated up to 660°C in the electric furnace. Red mud added to it in the form of particles in the ratios of 2% and 3% as a reinforcement. Mixture of MMC and reinforcement are stirred using iron rod which was zircon coated at a temperature of 640°c continuously for 4-5 minutes and the liquid nitrogen gas was then allowed to pass through the mould. Proper arrangements were made for simultaneous pouring of molten metal. The specimens were prepared both with and without the chill casting. The study conducted concluded that the metal matrix Al 7075 is reinforced with red mud by using chill casting process to attain rapid solidification. Liquid nitrogen was hence used for the rapid solidification of molten metal. The red mud reinforcement was added in the ratios of 2% , 3% and mixed with molten metal. The composites are prepared both of with chill and without chilling effect. The primary defects in the alloys like holes, porosity, and cracks propagate during rapid solidification and the liquid solute rejected solidified part of the material cause's micro segregation. Micro segregation propagates rapidly under cooling conditions. By considering these conditions the final results concluded that strength in tension, impact and surface hardness, will decrease in case of with chilled components as compared with without chilled components.

Mani Sambathkumar et al[17] Investigated Al 7075 metal matrix composites for various properties. Al 7075 MMC was prepared using red mud as a reinforcement using stir casting. Volume of reinforcement was varied from 0% to 15%. The density of the MMC produced found to be greater than that of the basic matrix. There reinforcement was seen as homogeneous from optical micrographs. Vickers hardness testing machine was used to measure. The MMC developed exhibited a better resistance to corrosion compared to the base metal matrix. Increase in percentage of red mud resulted in reduction in the rate of corrosion.

3. Findings of Literature

Researchers have contributed for Production of Al 7075 composites. They mentioned preparation of test specimens from the samples extracted which are 'free from defects regions' of the composites. Experimental determination of mechanical, thermal and tribological parameters, namely, tensile properties, compressive properties, thermal conductivity and wear resistance as influenced by reinforcement size, holding temperature, weight percent and holding time, corresponding to composites in the as-cast condition is mentioned in the literature communicated. Developing mathematical models (by regression) correlating the selected process parameters, in each case, with the responses, to predict the influence of the former on the responses of the later is also carried out for squueze cast specimen. However, the effect of stir casting process on Mechanical, thermal and tribological properties of Aluminium – 7075 reinforced with red mud/fly ash metal matrix composite has not been reported in the literature communicated.

4. Conclusions

It is essential to undertake the research problem to evaluate the change in Mechanical, tribological, thermal properties of Aluminium – 7075 reinforced with reinforcement as red mud, fly ash MMC developed by implementing stir casting. The test pieces will be prepared and will be examined for determining the mechanical, thermal and tribological properties. The experimental results obtained will be considered to evolve the mathematical models and the responses will be analyzed as a guideline for their uses in working conditions subjected to corrosive environment.

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