*Int. J. Mech. Eng. & Rob. Res. 2013*

International Journal of Mechanical Engineering and Robotics Research

*ISSN 2278 – 0149 www.ijmerr.com*
*Vol. 2, No. 4, October 2013*


*Research Paper*

# EFFECT OF REINFORCEMENT OF FLYASH ON THE STRUCTURE AND PROPERTIES OF ALUMINIUM 2024 ALLOY WITH HEAT TREATMENT

Madhusudan K[1]* and B S Reddappa[1]

*Corresponding Author: Madhusudan K, ✉ catchmadhunow@gmail.com

In the present investigation, an attempt is made to study the effect of reinforcement of Flyash on aluminium 2024 alloy, subjected to heat treatment. The cast composites were tested for hardness, wear characteristics and the obtained properties were correlated with the microstructure. The results of the present investigation indicate that there is a considerable improvement in the hardness values, microstructure and resistance for wear.

Keywords: Aluminium 2024 alloy, Composite, Flyash, Heat treatment, Microstructure

## INTRODUCTION

Conventional 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 many advantages over monolithic materials, including higher specific strength, good wear resistance, higher thermal conductivity than ceramic materials, lower coefficient of thermal expansion compared to unreinforced alloys. There has been an increasing interest in composites containing low density and low cost reinforcements.

Among various discontinuous dispersoids used, fly ash is one of the most inexpensive and low density reinforcement available in large quantities as solid waste by-product during combustion of coal in thermal power plants. It is therefore expected that the incorporation of fly ash 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.

1 Department of Mechanical Engg., M. S. Ramaiah Institute of Technology, Bangalore 54, India.

In the present investigation, an attempt is made to develop the heat treated composite involving aluminium matrix reinforced with particulates of flyash (produced by stir casting technique), the cast composites were tested for hardness property, dry sliding wear properties and microstructure.

## EXPERIMENTAL PROCEDURE

The details of the experiments carried out on Al2024 alloy subjected to reinforcement of Flyash and with T6 heat treatment has been highlighted under the following headings.

- Selection of materials
- Melting and casting
- Heat treatment process

### Selection of Materials

#### Matrix Material

The base matrix chosen in the present study is the aluminium 2024 because it is one of the most extensively used of the 2000 series aluminium alloys. Alloy 2024 is an aluminium alloy containing copper as a major alloying element. They have high strength to weight ratio, good formability, age hardenability and other appropriate properties. Among Al alloys, Al 2024 has high machinability, high hardness property and also light weight. But some of the mechanical properties such as low wear resistance have limited application of these materials. Al2024 is used in consumer products and military applications. The aircraft and aerospace industry uses aluminium alloys because it is much lighter than steel and every kilogram of weight reduction results in greater fuel savings and higher payloads. The car industry has increased its use of aluminium over the years as the price of gasoline has increased and the need to reduce vehicle weight has been of paramount importance. Today, much of aluminium use is to reduce the weight of the item being produced.

#### Reinforcing Material

Fly ash is one of the residues generated in the combustion of coal. It is an industrial by-product recovered from the flue gas of coal burning electric power plants. In general, fly ash consists of $SiO_2$, $Al_2O_3$ and $Fe_2O_3$ as major constituents and oxides of Mg, Ca, Na, K, etc., as minor constituent. Fly ash particles are mostly spherical in shape and range from less than 1 μm to 100 μm. They have relatively low density, around 2.0-2.5 g/cc. Coal fly ash has many uses including as a cement additive, in masonry blocks, as a concrete admixture, as a material in lightweight alloys, as a concrete aggregate, in flowable fill materials, in roadway/runway construction, in structural fill materials, as roofing granules, and in grouting.

### Melting and Casting

- Production of the Metal Matrix Composite (MMC) through stir casting technique.
- The Al2024 alloy melts at a temperature of 800 °C in a graphite crucible in melting furnace and degassing was carried out using hexa-chloroethane degassing tablets.
- The stirring device was a stainless steel rod, which was equipped with four stirring blades, each 1 mm thick. The blades were mounted radial on the rotating rod, being angled 5° to the radial horizontal rotational plane.
- The addition of Flyash will be added on the percentage weight of the aluminium alloy.

- The mixture starts from 2% by weight and will go on up to 12% by weight, with the increment of 2% per trial.
- The molten alloy was stirred at 250 rpm for up to 1 min until a vortex is formed. Preheated Flyash particles at 200 °C was added into the formed vortex slowly and steadily while continuing stirring for 3-5 min in a manoeuvring way to ensure the complete insertion of particles.
- The molten metal will be poured into preheated finger mould die.

Figure 1: Electric Furnace

Figure 2: Stirring Process

### Heat Treatment Process

The Aluminium composites were heat treated and tempered to T6 condition, i.e., the samples were heated at 530 °C for 3 hours and then immediately quenched in water at room temperature and finally were artificially aged in the furnace at 190 °C for 5 hours and then air cooled to room temperature.

## EXPERIMENTAL DETAILS

### Hardness Test

Hardness is the property of a material that enables it to resist plastic deformation, usually by penetration. However, the term hardness may also refer to resistance to bending, scratching, abrasion or cutting. Hardness is not an intrinsic material property dictated by precise definitions in terms of fundamental units of mass, length and time. A hardness property value is the result of a defined measurement procedure. This deformation may be in the form of scratching and mechanical indention or cutting. Indenters in the form of spheres and cones are frequently used. Hardness of the material was found out on Brinell hardness testing machine. The testing machine is the most widely used method to determine hardness. Brinell hardness was carried out as follows:

- The specimen or the area or location must be selected and polished so as to give a reliable indication of the properties of the material.
- The specimen was placed on the anvil so that the surface is normal to the direction of applied load.
- The anvil is raised by means of elevating screw.

- Now, raise the anvil, the pointer comes to the red dot on the dial [i.e., it indicates the application of minor load (10 kg) acting on the indenter. This is done to ensure the perfect seating and loading of the specimen].
- Apply the major load (60 kg) with a 5 mm diameter steel ball indenter and wait for 30 seconds duration, to ensure the complete acting of the load on the specimen by the indenter.
- Remove the load after 30 seconds, measure the indentation by using travelling microscope and find out the BHN using formula.
- The indentations were taken at three points on each specimen. Figure 3 shows the hardness tester and the hardness specimen.

Figure 3: Brinell Hardness Testing Setup


The BHN is calculated according to the formula given below:

$$BHN = 2P/(\Pi D(D-\sqrt{(D2-d2)})$$

where,

P (Load Applied) = 60 kg, D (Dia of Ball Indenter) = 5 mm, d (Dia of Indentation)

### Wear Test (Dry Sliding Wear)

- The Figure 4 shows the Pin on Disc Sliding Wear testing apparatus. The disc is rotated by means of an electric motor and the loads of 1 kg, 1.5 kg and 2 kg has been applied and the wear is calculated which is the measure of weight loss of the specimens.
- The velocity of the disc has been set to 400 rpm and 800 rpm and the wear loss in micrometers of the pin has been tabulated for 10 minutes constant. The track diameter of rotation has been kept at 130 mm of the disc.
- Weight loss was considered for wear analysis (i.e., the difference between the initial and final weight). The formula used for finding weight loss and wear rate is as shown below:

Figure 4: Pin on Disc Setup

Weight Loss (WL) = Initial weight – Final weight = W1 – W2 grams

### Microstructure Examination

The study of Microstructure forms important part of the experiment. Microstructure will help in characterization of composition structure and properties of the material. Steps involving in the preparation of specimen for microstructure examination are given below.

**Sectioning:** The specimen is prepared by sectioning for the required dimension by fixing to the hand wise and the cutting of the material by using a hack saw blade. The specimen was section using suitable abrasive wheel cutter. Sharp edges, burrs and any intervening deformed material was removed by rough grinding using an abrasive belt grinder.

**Grinding:** The surface is prepared for the microstructure by removing the irregularity. The surface is prepared by polishing the specimen for microstructure was carried out using 80, 120, 220, 400, 800, 1000, 1200, 2500 and 3000 grade water proof emery paper for a period of 5 mins for each paper.

Figure 5: Prepared Specimens for Microstructure Analysis

**Polishing:** The specimens were then polished by using diamond paste on a mescaline cloth.

**Etching:** Etching is a process of cleaning the top surface. Etching is carried out for a period of ten seconds. Samples were etched to reveal the grain structure using Keller's reagent. 100 ml of Keller's reagent was prepared by adding $HNO_3$ 2.5 ml, HCL 1.5 ml, HF 1 ml and $H_2O$ 95 ml, after etching samples were washed and dried thoroughly.

## RESULTS AND DISCUSSION

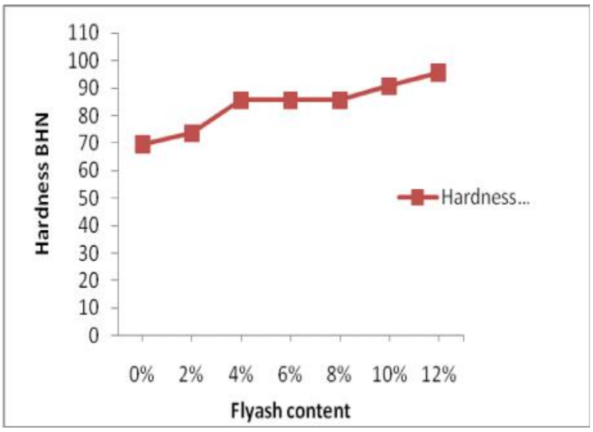
The results of the investigation carried out on the grain refinement of Al-Si alloy subjected to mechanical vibration with and without the addition of refiner and T6 heat treatment discussed under the following headings.

- Hardness test
- Microstructure examination
- Dry sliding wear test.

### Hardness Test

The below graph shows that incorporation of fly ash particles in Aluminium matrix causes reasonable increase in hardness. The

Figure 6: Shows the Variation of Hardness Valves for Different Specimen



strengthening of the composite can be due to dispersion strengthening as well as due to particle reinforcement.

## Microstructure Examination

Figure 7 shows the Microstructure of as cast Al2024 alloy. The Microstructure consists of fine grains of aluminium solid solution with a fine dispersion of inter-metallic precipitates. No reinforcement is seen.

Figure 7: Microstructure of As-Cast Al2024 Alloy

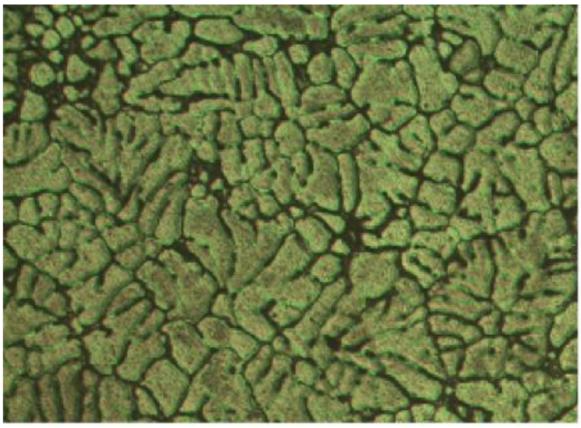


Figure 8 shows the microstructure of 2% flyash composite. Microstructure consists of dendrites of aluminium solid solution with inter-metallic precipitates at the inter-dendritic regions. Reinforcement particles were seen. There is a slight grain refinement when compared to as-cast alloy.

Figure 8: 2% Flyash

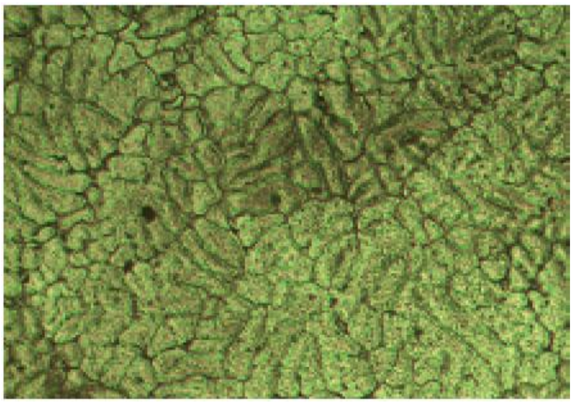


Figure 9 shows the microstructure of 4% flyash composite. Microstructure consists of dendrites of aluminium solid solution with inter-metallic precipitates at the inter-dendritic regions. Reinforcement particles were seen. There is further grain refinement when compared to 2% flyash composite.

Figure 9: 4% Flyash

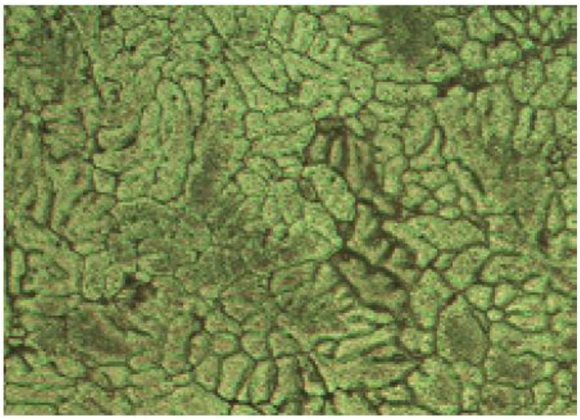
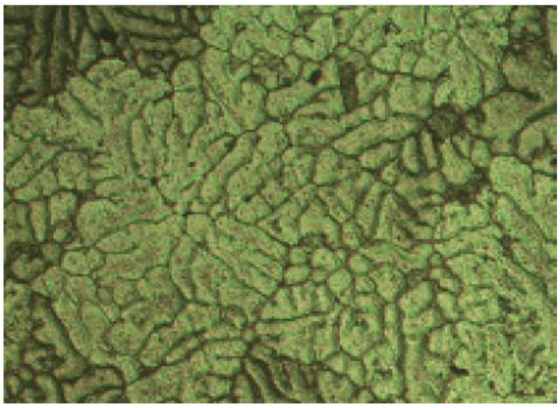


Figure 10 shows the microstructure of 6% flyash composite. Microstructure consists of dendrites of aluminium solid solution with inter-metallic precipitates at the inter-dendritic

Figure 10: 6% Flyash



regions. Reinforcement particles were seen. The grains are well refined.

Figure 11 shows the microstructure of 8% flyash composite. Microstructure consists of dendrites of aluminium solid solution with inter-metallic precipitates at the inter-dendritic regions. Reinforcement particles were seen. The grains are well refined.

Figure 11: 8% Flyash

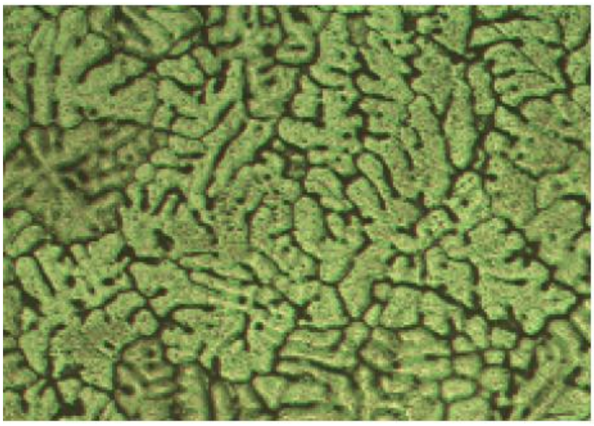


Figure 12 shows the microstructure of 10% flyash composite. Microstructure consists of dendrites of aluminium solid solution with inter-metallic precipitates at the inter-dendritic regions. Reinforcement particles were very well seen.

Figure 12: 10% Flyash

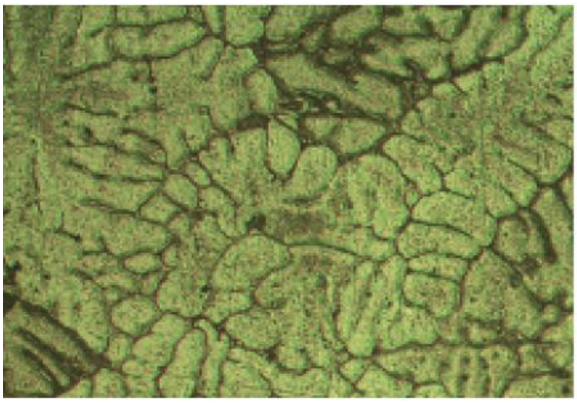
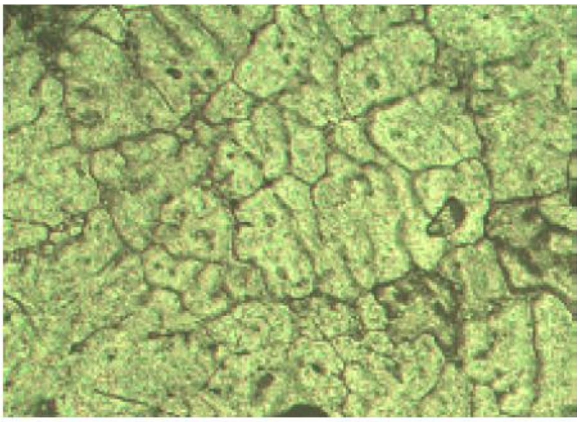


Figure 13 shows the microstructure of 12% flyash composite. Microstructure consists of dendrites of aluminium solid solution with inter-metallic precipitates at the inter-dendritic regions. Reinforcement particles were very well seen.

Figure 13: 12% Flyash



## Wear Test

The Figures 14 and 15 show that the wear resistance of the composites has increased with increase in flyash content. This may be due to the presence of hard flyash particles, which will increase the overall bulk hardness of the material. In the initial wear regime, the

Figure 14: Comparison of Weight Loss v/s Various Specimen at 400 rpm and Loads 1 kg, 1.5 kg and 2 kg After Treatment

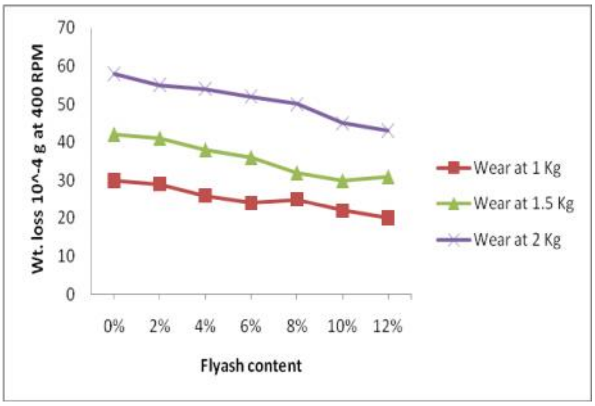
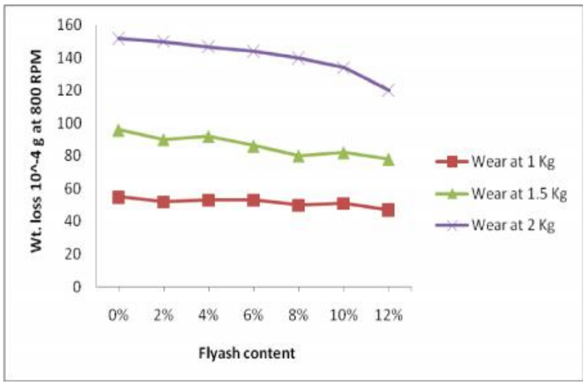


Figure 15: Comparison of Weight Loss v/s Various Specimen at 800 rpm and Loads 1 kg, 1.5 kg and 2 kg After Treatment




reinforced particles act as load carrying elements and as inhibitors against plastic deformation and adhesion of matrix material. In the later stages of wear regime, the worn particles get dislodged from their positions in the matrix and get mixed with the wear debris.

## CONCLUSION

### Hardness

The Hardness of the composites increased with the increase in the flyash content. When compared to the as cast specimens, there is an improvement up to 50%. A maximum hardness value of 95.5 BHN is observed in the Specimen with 12% flyash reinforcement with heat treatment.

### Microstructure

The microstructure shows dendrites of aluminium solid solution with inter-metallic precipitates at the inter-dendritic regions, grain refinement with the increase in flyash content were seen. The grain structure gets reduced and a closed structure is observed when the alloy is subjected to Flyash reinforcement and with T6 Heat treatment.

### Wear Behaviour

There was a considerable improvement in the wear resistance of the flyash reinforced specimens with heat treatment. The wear has decreased with the increase in the flyash content. The improvement was in the range of 20% to 40% depending on various factors like disc speed, load, friction, etc.

## ACKNOWLEDGEMENT

The Authors express their sincere gratitude to the management, principal and HOD, Mechanical Engineering department, M.S.R.I.T. Bangalore for the support and the encouragement.

## REFERENCES

1. Aghajanian M K, Langensiepen R A, Rocazella M A, Leighton J T and Andersson C A (1993), *J. Mater. Sci.*, Vol. 28.
2. ASM Hand Book, Vol. 4, *Heat Treatment*, pp. 1862-1928.
3. ASM Hand Book, Vol. 8, *Mechanical Testing and Evaluation*, pp. 412-650.
4. Babu Rao J, Venkata Rao D and Bhargava N R M R (2010), "Development of Light Weight ALFA Composites", *Materials Science Forum*, Vol. 690.
5. Guo R Q and Rohatgi P K (1997), *Fuel and Energy Abstracts*.
6. Matsunaga T, Kim J K, Hardcastle S and Rohatgi P K (2002), "Crystallinity and Selected Properties of Fly Ash Particles", *Materials Science and Engineering A325*.
7. Matthews F L and Rawlings R D (1999), *Composite Materials: Engineering and Design*, Chapman & Hall Publication.

8. Miyajima T and Iwai Y (2003), "Effects of Reinforcements on Sliding Wear Behavior of Aluminum Matrix Composites", 14th International Conference on Wear of Materials, pp. 606-616.

9. Ramachandra M and Radhakrishna K (2007), "Effect of Reinforcement of Flyash on Sliding Wear, Slurry Erosive Wear and Corrosive Behavior of Aluminium Matrix Composite", Wear, Vol. 262, pp.11-12.

10. Ramasesh B S, Surappa M K and Pramila Bhai B N (1995), "Dry Sliding Wear of Al Alloy 2024-$Al_2O_3$ Particle Metal Matrix Composites", *Wear*, pp. 181-183.