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Research Article

The Experimental Analysis of Stir Casting Method on Aluminium-Fly Ash Composites

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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, 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. Hence, composites with fly ash 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 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. 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 fly-ash in useful manner by dispersing it into aluminium to produce composites by stir casting method.

Keywords: *particulate composites, industrial waste, applied load and sliding velocity*

1. 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 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, 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. Hence, composites with flyash 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 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.

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 .While investigating the opportunity of using fly-ash as reinforcing element in the aluminium melt, It is observed that the high electrical resistivity, low thermal conductivity and low density of fly-ash may be helpful for making a light weight insulating composites. 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 of the particulate due to poor wet ability and gravity regulated segregation.

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Mechanical properties of composites are affected by the size, shape and volume fraction of the reinforcement, matrix material and reaction at the interface. These aspects have been discussed by many researchers. My report is that with the increase in volume percentages of fly ash, hardness value increases in Al–fly ash (precipitator type) composites. He also reports that the tensile elastic modulus of the ash alloy increases with increase in volume percent (3–10) of fly ash. Aghajanian et al. have studied the Al2O3 particle reinforced Al MMCs, with varying particulate volume percentages (25, 36, 46, 52 and 56) and report improvement in elastic modulus, tensile strength, compressive strength and fracture properties with an increase in the reinforcement content. The interface between the matrix and reinforcement plays a critical role in determining the properties of MMCs. Stiffening and strengthening rely on load transfe across the interface. Toughness is influenced by the crack deflection at the interface and ductility is affected by the relaxation of peak stress near the interface. Extensive studies on the tribological characteristics of Al MMCs containing reinforcements such as SiC and Al2O3 is available in the literatures. However, reports on friction and wear characteristics of fly ash reinforced AMCs are very limited. It is reported that the addition of fly ash particles to the aluminium alloy significantly increases its abrasive wear resistance. I attributed the improvement in wear resistance to the hard alumina silicate constituent present in fly ash particles.

2. Experimental Procedures

First of all, 400 gm of commercially pure aluminium was melted in a resistance heated muffle furnace and casted in a clay graphite crucible. For this the melt temperature was raised to 993K and it was degassed by purging hexachloro ethane tablets. Then the aluminium-fly ash (5%,10%,15%,20%) composites were prepared by stir casting route. For this we took 400 gm of commercially pure aluminum and then (5, 10, 15, 20) wt% of fly ash were added to the Al melt for production of four different composites. The fly ash particles were preheated to 373K for two our to remove the moisture. Commercially pure aluminium was melted by raising its temperature to 993K and it was degassed by purging hexachloro ethane tablets. Then the melt was stirred using a mild steel stirrer. Fly-ash particles were added to the melt at the time of formation of vortex in the melt due to stirring. The melt temperature was maintained at 953K-993K during the addition of the particles. Then the melt was casted in a clay graphite crucible. The particle size analysis and chemical composition analysis was done for fly ash. The hardness testing and density measurement was carried out Al-(5, 10, 15, 20) wt% fly ash composites. The hardness of the samples was determined by Brinell hardness testing machine with 750 kg load and 5 mm diameter steel ball indenter. The detention time for the hardness measurement was 15seconds. The wear characteristics of Al-fly ash composites were evaluated using wear testing machine. For this, cylindrical specimens of 1.1 cm diameter and 2.1 cm length were prepared from the cast. Al- fly ash composites. Test was performed at under different loads and rpm for 10 minutes. The SEM was done for all the samples.

Fig .1. Stir Casting setup

3. Results and Discussion

3.1 Particle Size Analysis Of Fly Ash

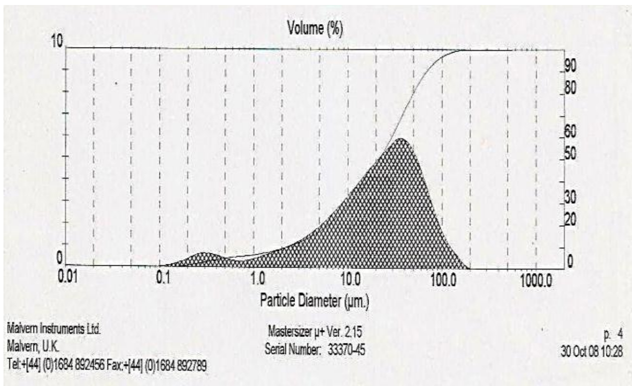

Fig .2. Particle size analysis

The size, density, type of reinforcing particles and its distribution have a pronounced effect on the properties of particulate composite. Size range of fly ash particles is reported in the above figure. The size range of the particles is very wide i.e. 0.1 micron to 100 micron. The size ranges of the fly ash particles indicate that the composite prepared can be considered as dispersion strengthened as well as particle reinforced composite. As is seen from the particle size distribution there are very fine particles as well as coarse ones (1-100 µm). Thus the strengthening of composite can be due to dispersion strengthening as well as due to particle reinforcement. Dispersion strengthening is due tote incorporation of very fine particles, which help to restrict the movement of dislocations, whereas in particle strengthening, load sharing is the mechanism.

Strengthening of matrix may occur because of solid solution strengthening.

The above table shows that incorporation of fly ash particles in Aluminium matrix causes reasonable increase in hardness. The strengthening of the composite can be due to dispersion strengthening as well as due to particle reinforcement. Thus, fly ash as filler in Al casting reduces cost, decreases density and increase hardness which are needed in various industries like automotive etc

3.2 Wear Behaviour

In the graphs below the colour coding is as follows:-

(1)Blue for Al-5% Fly ash
(2) Red for Al-10 % Fly ash
(3)Black for Al-15% Fly ash
(4) Green for Al-20% Fly ash

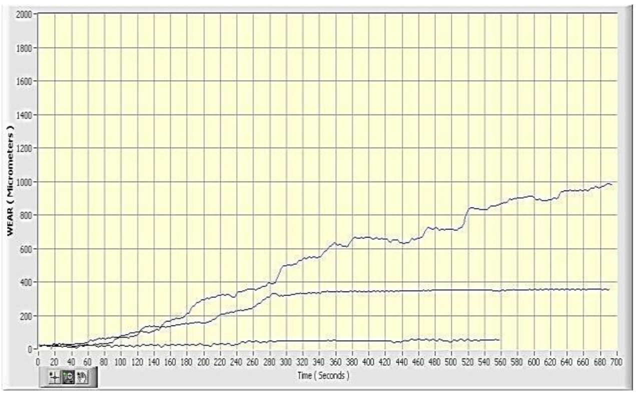

Fig 3 –Wear behaviour of MMCS with different % of Fly ash at 20N load and 240rpm.

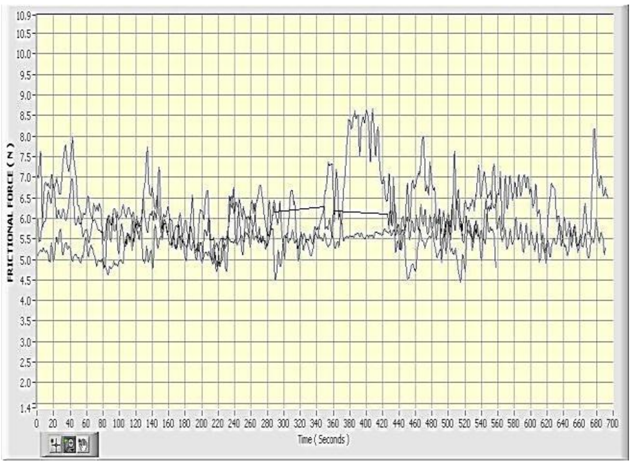

Fig 4 –Variation of Frictional force with different % of Fly ash at 20N load and 240 rpm.

application of a friction stir welding of the butt joints between aluminium AA6035 and AA8011 by changing the feed rate had influenced the microstructure and hardness of aluminium 6035 and 8011. The results are as follows Conditions speed 550 rpm.

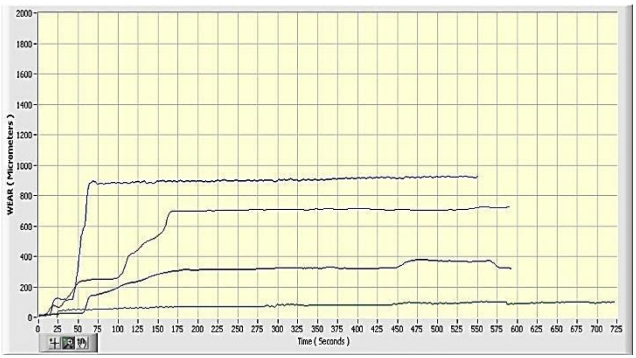

Fig.5 Wear behaviour of MMCS with different % of Fly ash at 50N load and 240rpm

Fig.6 Variation of Frictional force with different % of Fly ash at 50N load and 240 rpm.

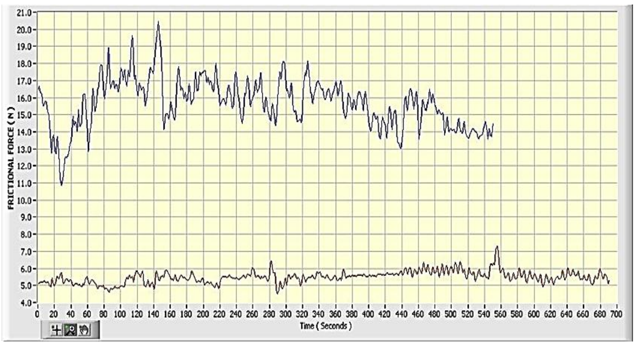

Fig 7 – Wear behaviour of Al-(20%)Fly ash composite at 20N load at 240rpm(red line) and 500

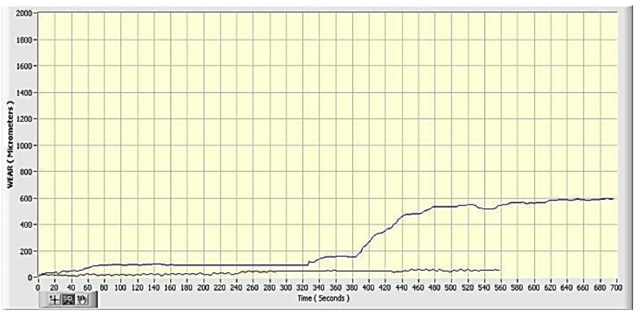

Fig 8 Variation of Frictional force for Al-(20%)Fly ash composite at 20N load at 240 rpm(red line) and 500 rpm(blue line).

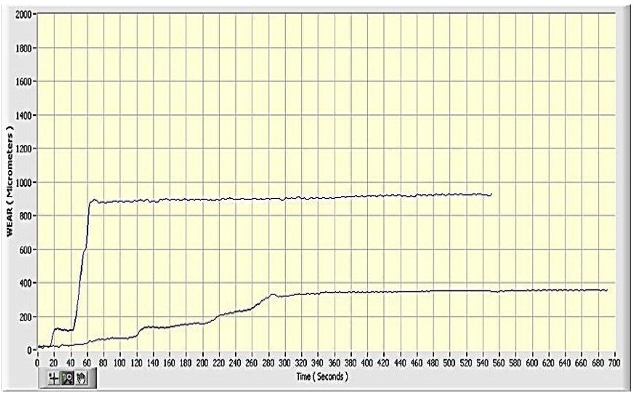

Fig 9 – Wear behavior of for Al-(5%)Fly ash composite at 240 rpm and at 20N(red line) and50N(blue line) load.

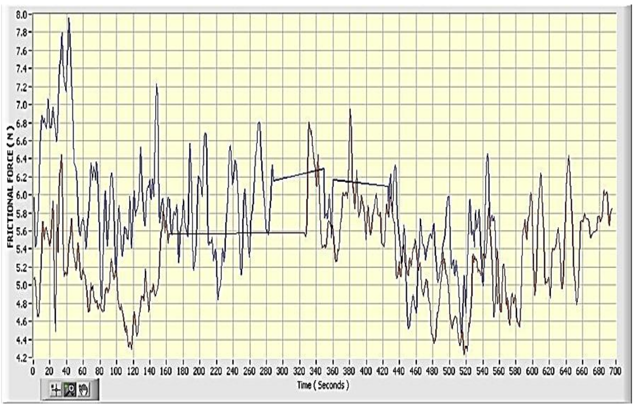

Fig 10 – Variation of Frictional force for Al-(5%)Fly ash at 240 rpm and at 20N(red line) and 50N(blue line) load.

The figure [4(e),4(f)] shows the variation of wear rate and frictional force with time of Al-20% fly ash at 20N load at 240 and 500 rpm. It shows that the wear rate has increased with the increase in rpm at constant load. The reason being the oxide particles are removed giving rise to three body wear and wear rate increases with increase in sliding velocity. The figure [4(g),4(h)] shows the variation of wear rate and frictional force with time of Al-5% fly ash at 20N and 50N load at 240 rpm. It shows that the wear rate has increased with the increase in load at constant rpm. Al-fly ash composites also have an increasing trend of wear with applied load due to deformation generation of cracks within the oxide film that may act as a three body wear on removal of the particles increasing the wear rate drastically at high loads. The addition of fly ash acts as a barrier to the movement of dislocations and thereby increases hardness of the composite. Thus addition of fly ash particles to the aluminium melt significantly increases its abrasive wear resistance. The improvement in wear resistance is due to the hard aluminosilicate constituent present in fly ash particles. From the view of material, influencing factors on friction force are mechanical properties of the matrix, hardness, chemical stability of the particles, composition and strength of the interface. Interaction between these and tribological parameters (such as load and speed, environment and the properties of the counter faces materials) are responsible for the overall response.

3.3 SEM analysis

SEM photographs were taken to analyze the fly ash particles and surfaces of Al-(5%,20%) fly ash composites.

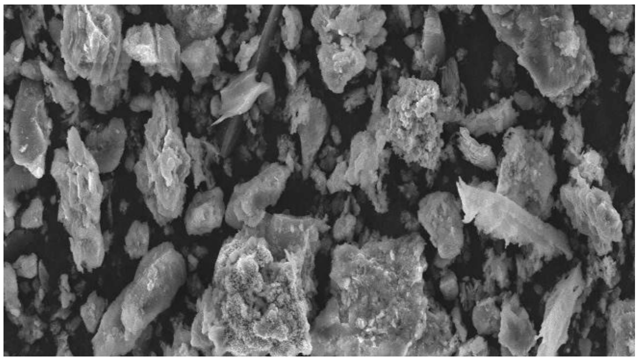

Fig 11 SEM micrograph of Fly ash particles

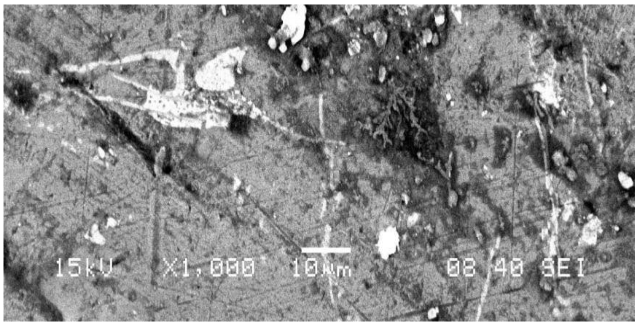

Fig 12 SEM micrograph of as Al-5%fly ash composite

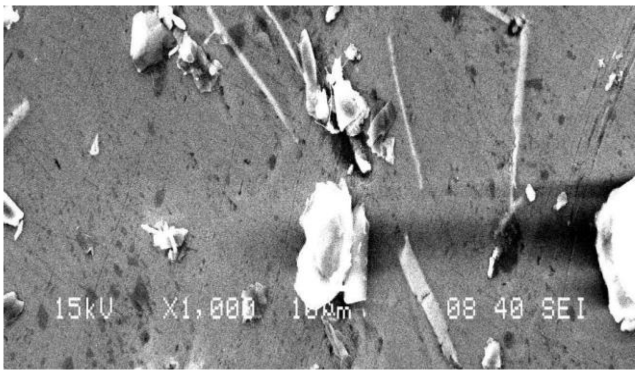

Fig 13 SEM micrograph of Al-20% fly ash composite

The figure 4.5(a) shows that the fly ash particles consist of precipitator particles. The figure [4.5(b),(c)] shows that with increase in percentage of fly ash there is increase in incorporation of fly ash in the composites.

Thermodynamic analysis indicates that there is a possibility of chemical reaction between aluminium melt and fly ash particles. As these fly ash particles consist of alumina, silica and iron oxide, they are likely to undergo chemical reduction during their contact with the melt, as follows:

$2Al(l) + 3/2SiO_2(s) = 3/2\ Si(s) + Al_2O_3(s)$…… (1)

$2Al(l) + Fe_2O_3(s) = 2Fe(s) + Al_2O_3(s)$…… (2)

The elements (Si and Fe) formed by reduction reaction would alloy with the matrix. Gibbs free energy and the heats of reactions are highly exothermic in nature. As a result of this reaction (Eq. (1)) greater amount of eutectic silicon is seen in the composites

Conclusions

1. From the study it is concluded that we can use fly ash for the production of composites and can turn industrial waste into industrial wealth. This can also solve the problem of storage and disposal of fly ash.
2. Fly ash upto 20% by weight can be successfully added to Al by stir casting route to produce composites.
3. The hardness of Al-fly ash composites has increased with increase in addition of fly ash.
4. Both the frictional forces and the wear rates have decreased significantly with the incorporation of fly ash in Al melt.
5. Strengthening of composite is due to dispersion strengthening, particle reinforcement and solid solution strengthening

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