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Original Research Article

EXPERIMENTAL ANALYSIS ON ALUMINIUM COMPOSITE MATERIAL WITH FLY ASH

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Abstract - Consisting of two or more physically and chemically distinct phases will make composite material. The composite generally has superior characteristics than those of each of the individual components. There has been an increasing interest in composites containing low density and low cost reinforcements. Usually the reinforcing component is distributed in the continuous or matrix component. Fly ash is a very fine material which is produced by burning of pulverized coal in boilers of thermal power plants. The fly ash is sent to ash ponds in the form of slurry with water since it is economical. This fly ash being finer and lighter than river sand has lower settlement rate, which can be increased by adding a suitable polymer to the ash slurry in the pond. Among various reinforced materials used, fly ash is one of the most inexpensive and low density reinforcement available in large quantities as waste product during combustion of coal in thermal power plants as well as in the brick factory and rice mill. 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. The present investigation has been focused on the utilization of abundantly available industrial and domestic waste fly-ash in useful manner by dispersing it into aluminium to produce composites by casting method. In this work two type of casting has to be obtain by MMC and compare their mechanical properties in between them.

Keywords- Reinforcements, pulverized coal, fly ash, MMC, casting

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Introduction: Aluminium alloys are used in advanced solicitations because their combination of high strength, low density, durability, machinability, availability and cost is very attractive compared to competing materials. 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. It is therefore expected that the assimilation 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 aluminum and thereby, reducing the cost of aluminum products. Now a days the particulate reinforced aluminum 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.

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 composites 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 amalgams 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 encourage 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 aluminum products.

MMCs are defined as ductile matrix materials reinforced by particles. Under external loading conditions the overall response of MMCs is elastic-plastic. MMCs are frequently reinforced by continuous plastic which are aligned in order to make use of the high axial composite strength. The aspect ratio of the reinforcement is an important quantity, because the degree of load handover from thematrix to the reinforcement is directly proportional to the reinforcement aspect ratio. Liquid-phase infiltration of MMCs is not straight forward, mainly because of difficulties with wetting the ceramic reinforcement by the molten metal.

The advantage of this method is that the temperatures involved are moderate and no damage is done to the fibers. Problems with electroplating involve void creation between fibers and between fiber layers, possible poor adhesion of the deposit to the fibers, and limited numbers of alloy matrices available for this type of processing. A spray deposition operation may also be used. This technique typically consists of winding fibers onto a foil-coated drum and spraying molten metal onto the mto form a monotape. Thus, the accurate modelling of the mechanical behavior of actual MMCs is very complicated in practice even if the fibers are aligned. The source of molten metal may be powder or wire feedstock which is melted in aflame, arc, or plasma torch. The advantages of spray deposition are the easier control of fib reorientation and rapid solidification of the molten matrix. In the CVD process, a vaporized component decomposes or reacts with another vaporized chemical on the substrate to form a coating on that substrate.

Metal Matrix Composites: Metal matrix composite materials have found application in many areas of daily life for quite some time. Materials like cast iron with graphite or steel with high carbide content, as well as tungsten carbides, consisting of carbides and metallic binders, also belong to this group of composite materials. These demands can be achieved only by using non-metal inorganic bolstering components. Metal matrix composites become interesting for use as constructional and functional materials, if the property profile of conventional materials either does not reach the increased standards of specific demands, or is the solution of the problem. The reinforcement of metals can have many different objectives;

- Increase in yield strength and tensile strength at room temperature and above while maintaining the minimum ductility or rather toughness,
- Increase in creep resistance at higher temperatures compared to that of conventional alloys,
- Increase in fatigue strength, especially at higher temperatures,
- Improvement of thermal shock resistance,
- Increase in Young's modulus,
- Reduction of thermal elongation.

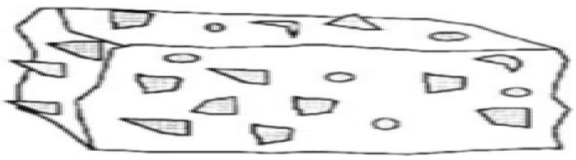

Fig. 1. Metal matrix composite (Particle)

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. However, MMC technology is still in the early stages of development, and other essential systems undoubtedly will emerge. Numerous metals have been used as matrices. The most important have been aluminum, titanium, magnesium, and copper alloys and super alloys. 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 ingredients (physical property of steel are similar to those of pure iron) . Favorable properties of composites materials are high stiffness and high strength, low density, high temperature stability, high electrical and thermal conductivity, adjustable coefficient of thermal expansion, corrosion resistance, improved wear resistance etc. Composite materials are classified as

- On the basis of matrix material,
- On the basis of filler material.

Fly Ash: 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. Depending upon the source and makeup of the coal being burned, the components of the fly ash produced vary substantially, but all fly ash includes substantial amounts of silica. Fly ash particles are classified into two types, precipitator and cenosphere. Generally, the solid spherical particles of fly ash are called precipitator fly ash and the hollow particles of fly ash with density less than 1.0 g cenosphere fly ash. One common type of fly ash is commonly composed of the crystalline compounds such as quartz, mullite and hematite, glassy compound such as silica glass, and other oxides.

Categories of Fly Ash: The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash. This fly ash is pozzolanic in nature, and comprehends less than 10% lime (CaO). Retaining pozzolanic properties, the glassy silica and alumina of Class F fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime, with the presence of water in order to react and produce cementitious compounds. Alternatively, the addition of a chemical activator such as sodium silicate (water glass) to a Class F ash can leads to the formation of a geopolymer. Fly ash produced from the burning of younger lignite or sub bituminous coal, in addition to having pozzolanic properties, also has some self-cementing properties. In the presence of water, Class C fly ash will harden and gain strength over time. Class C fly ash commonly contains more than 20% lime (CaO). Unlike Class F, self-cementing Class C fly ash does not require an activator. Alkali and sulfate (SO_4) contents are generally higher in Class C fly ashes.

Problem Description: The present investigation has been focused on exploitation of waste fly ash in useful manner by dispersing it in aluminum matrix to produce composite. In the present work, fly-ash which mainly consists of refractory oxides like silica, alumina, and iron oxides, was used as the reinforcing phase and to increase the wet ability magnesium and silicon were added. Composites were created with different percentages of reinforcing phase. Mechanical properties of the composites were also evaluated.

The SiC particles are the most common intermittent reinforcements in Al matrix composites although the density of SiC is slightly higher than that of Al. This is because it is inexpensive and readily available but still gives the composite high strength and elastic modulus. The improved wear resistance is often the primary feature as well. In the same way as in the case of continuous SiC fibres the possibility of chemical reactions limits the high temperature applications and may cause problems in production. Excess Si reduces the reactivity of SiC in A1 remarkably. Another widely used particulate reinforcement in Al matrix composites is Al203. In comparison to SiC it is much more inert in Al and it is also oxidation resistant. Accordingly, it is much more suitable for high temperature fabrication and use. In order to overcome the problem of poor wettability of A1203 by A1, which disturbs especially the liquid stirring production routes, the matrix is alloyed or the reinforcement is surface coated. As described previously, Li is found to be a constructive alloying element. MgO on the surfaces of A1203 is also improving the wet ability. On the other hand, in squeeze casting the wet ability is not as large problem as in liquid stirring. Therefore, this efficient technique has been often utilized in production of particulate A1203 reinforced Al matrix composites. In fact, this amalgamation of production method and composite material Al is currently the most promising candidate for large scale production of relatively inexpensive MMCs for general Al applications.

Objective

The material costs of composites can be reduced significantly by incorporating fly ash into the matrices of polymers and metallic alloys. However, very little evidence is available on to aid in the design of composite materials, even though attempts have been made to incorporate fly ash in both polymer and metal matrices. Fly ash has a lower density than talc and calcium carbonate, but slightly higher than hollow glass. The cost of Fly ash is likely to be much lower than hollow glass. Fly ash may turn out to be one of the deepest cost fillers in terms of the cost per volume. The high electrical resistivity, low thermal conductivity and low density of fly-ash may be helpful for making a light weight segregating composites. Fly ash as a filler in Al casting reduces cost, decreases density and increase hardness, stiffness, wear and abrasion resistance. It also improves the maintainability, damping capacity, coefficient of friction etc. which are needed in countless industries like automotive etc. This reduces the generation of greenhouse gases as they are produced during the bauxite processing and alumina reduction.

Preparation of MMC of Al and Fly Ash: First of all, 400 gm of commercially pure aluminum was melted in a resistance passionate 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. For this material took 400 gm of commercially pure aluminum and 40 gm of fly ash. The fly ash particles were preheated to 373K for two hours to remove the moisture. Commercially pure aluminum was melted by raising its temperature to 993K and it was degassed by riddance 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. The particle size analysis and chemical composition analysis was done for fly ash. The hardness testing and density measurement was carried out for both commercially pure Al and Al-15% fly ash composite. The hardness of the samples was dogged by Brinell hardness testing machine with 500 kg load and 10 mm diameter steel ball indenter. The detention time for the hardness measurement was 30 seconds. The wear characteristics of commercially pure Al and Al-15% fly ash composite were appraised using wear testing machine. For this, cylindrical specimens of 10 mm diameter and 20 mm length were prepared from the cast aluminium and Al-15% fly ash composite.

Heat Treatment of Fly Ash: The fly ash in the composite heat treatment is done on it to eliminate impurities and water content. For the surface treatment of ash it is heated in the furnace at a temp. of 600°C. During this temperature range ethanol solution is added at a temp. of 50°C and stir for some time. After it we also added cover11 to improve its surface characteristics. The heat treatment of fly ash that taken from the ethanol dealing is to reduce moisture of mixed material in the induction furnace. After it we have to melt the Al 7075 in the furnace having a capacity of 1000°C and then added preheated fly ash into it.For accumulative wettability, we also added the Mg that means it decreases the surface tension of the fly ash. For better mixing of all materials, a stirrer arrangement is adjusted which stirs the molted composite material. AlsoHexachloro-ethane tablets are using here to remove the slag from the molten MMC. After all of these, this molten material will be emptied into the sand mould and fabricate the required shape of slab and rods.

The fly ash particles were preheated to 600ºC for 2 hours in a dispersed muffle furnace to remove the moisture content. Aluminium was charged in to the graphite crucible, and the furnace temperature was raised up to liquidtemperature 750ºC in order to melt the Al scraps completely and further the melt temperature was dropped to just below the liquids temperature to achieve the semi solid state. Magnesium and then preheated fly-ash particles were added in the crucible. Mg was incorporated into the melt to promote the wetting action between Al matrix and fly ash reinforcement particles. The molten Al composite slurry was stirred at the stirrer speed of 300 rpm for 20 minutes. Since high torque was needed in mixing of the composite slurry in semi solid state, a variable torque - speed controlled mechanical stirrer was employed. The diffusion of fly ash and magnesium with aluminium were achieved by the two step stir casting method. Finally the composite melt was reheated to 750ºC and poured into the steel mould to solidify.

Thermal Analysis of MMC: The thermodynamic analysis indicates that there is opportunity between the reaction of Al melt and the fly ash particles. The particles contain alumina, silica and iron oxide which during solidification process of Al fly ash composites or during holding such composites at temperature above 850 C, are likely to undergo chemical reactions. The experiments indicate that there is a progressive reduction between SiO_2, Fe_2O_3 and mullite by Al. The size, density, type of reinforcing particles and its scattering 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. The size ranges of the fly ash particles indicate that the composite arranged can be considered as dispersion strengthened as well as particle reinforced composite.

Preparation of MMC of Al And Plastic Waste: Waste plastic are chopped in small piece by machining. Commercially pure aluminium was melted by raising its temperature to 993K and it was degassed by purging hexachloro ethane tablets. Plastic waste particles were added to the melt at the time of materialization of vortex in the melt due to stirring. The melt temperature was maintained at 953K-993K during the addition of the particles. The particle size analysis and chemical composition analysis was done for plastic piece. The hardness testing and density measurement was carried out for both commercially pure Al and Al-13% plastic piece composite. The hardness of the samples was determined by Brinell hardness testing machine with 500 kg load and 10 mm diameter steel ball indenter. The detention time for the hardness measurement was 30 seconds. The wear appearances of commercially pure Al and Al-13% plastic piece composite were evaluated using wear testing machine. For this, cylindrical specimens of 10 mm diameter and 20 mm length were prepared from the cast aluminium and Al-13% plastic piece composite. Test was performed at 68.67 N load and 500 rpm for 10 minutes. Same process will repeated for 15% and 17% plastic piece composite.

Melting and Casting: The aluminum fly ash metal matrix composite was arranged by stir casting route. For this we took 400gm of commercially pure aluminum and desired amount of fly ash particles. The fly ash particle was preheated to 300^0C for three hour to remove moisture. Commercially pure aluminum was melted in a resistance furnace. The melt temperature was raised up to 720^0C and it was degassed by purging hexachloroethane tablets. Then the melt was stirred with the help of a mild steel turbine stirrer. The stirring was preserved between 5 to 7 min at an impeller speed of 200 rpm .The melt temperature was maintained 700^0C during addition of fly ash particles. The dispersion of fly ash particles were achieved by the vortex method. The melt with reinforced particulates were poured into the preheated permanent metalicmold. The pouring temperature was sustained at 6800C.The melt was then allow to solidify the moulds.

Mechanical Properties

Hardness Test: Hardness measurements were carried out on the base metal and composite samples by using standard Brinnel hardness test. Brinnel hardness quantities were carried out in order to investigate the influence of particulate weight fraction on the matrix hardness. Load applied was 750kgs and indenter was a steel ball of 5 mm diameter. Macroscopic hardness is generally characterized by strong intermolecular bonds. There are three types of tests used with accuracy by the metals industry; they are the Brinell hardness test, the Rockwell hardness test, and the Vickers hardness test. But in our present work we deliberated only Rockwell hardness test. The Rockwell scale is a hardness scale based on the indentation hardness of a material. The Rockwell test determines the hardness by measuring the depth of penetration of an indenter under a large load compared to the infiltration made by a preload.The tests determine the depth which such a ball or cone will sink into the metal, under a given load, within a specific period of time. Brinellhardness test has been achieved in this work.

$$BHN = \frac{F}{\frac{\pi}{2} D.(D - \sqrt{D^2 - D_i^2})}$$

BHN = the Brinell hardness number

F = the imposed load in kg

D = the diameter of the spherical indenter in mm

D_i = diameter of the resulting indenter impression in mm

Toughness Test: The toughness is the energy involves breaking the material. The energy is calculated in jouls. The energy consumed is calculated by the difference between total energy supplied to the energy available at the end. The measure of toughness can be found with the help of Charpy and Izod impact tests. The standard specimen size for Charpy impact testing is 10mm×10mm×60mm. and forIzod impact testing 10mm×10mm×70mm. The Charpy impact test, also known impact test as the Charpy V-notch test, is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture.

Result and Discussion: In this case two type of MMC has to be obtain, one is mixture of aluminum and plastic, second is mixture of aluminum and fly ash. These MMC are casting in permanent thickness and tested their mechanical properties (tensile, impact test and hardness test). Both MMC are casting by increasing their amount of substitute material. Aluminum alloy has been made on three different temperature (i.e. 450^{o}C, 475^{o}C & 500^{o}C) and use type of cooling to obtain best hardness and strength.

Hardness Measurement: Indentation hardness measures the confrontation of a sample to material deformation due to a constant compression load from a sharp object; they are primarily used in engineering and metallurgy fields.

Measurement of the macro-hardness of materials is a quick and simple method of winning mechanical property data for the bulk material from a small sample. It is also widely used for the quality control of surface treatments processes.

Table.1 Hardness Comparison of fly ash composite material

Substitute Material	Type of cooling	Hardness 300gm Aluminium BHN	Hardness 400gm Aluminium BHN	Hardness 450gm Aluminium BHN
10% Fly ash Material	Water Cool	92	96	95
	Air Cool	84	83	82
	Oil Cool	86	88	93
12% Fly ash Material	Water Cool	81	87	85
	Air Cool	75	81	88
	Oil Cool	72	83	86
15% Fly ash Material	Water Cool	81	86	84
	Air Cool	83	83	82
	Oil Cool	86	84	82
18% Fly ash Material	Water Cool	80	82	84
	Air Cool	79	78	80
	Oil Cool	74	72	83

Table2. Impact failure load Comparison of fly ash composite material

Substitute Material	Type of cooling	Impact Failure Load 300gm Aluminium (KN)	Impact Failure Load 400gm Aluminium (KN)	Impact Failure Load 450gm Aluminium (KN)
10% Fly ash Material	Water Cool	103	109	107
	Air Cool	101	100	104
	Oil Cool	98	103	100
12% Fly ash Material	Water Cool	92	103	98
	Air Cool	93	99	96
	Oil Cool	100	104	101
15% Fly ash Material	Water Cool	94	104	97
	Air Cool	88	96	91
	Oil Cool	93	97	94
18% Fly ash Material	Water Cool	92	94	93
	Air Cool	87	96	92
	Oil Cool	86	92	96

Conclusions: Hardness increased with the increase in the weight fraction of reinforced fly ash and decreased with increase in particle size of the fly ash. The ductility of the amalgamated decreased with increase in the weight fraction of reinforced fly ash and decreased with increase in particle size of the fly ash. The enhancement in the mechanical properties can be well attributed to the high dislocation density. Hardness of commercially pure aluminium is increased from 57BHN to 86BHN with accumulation of fly ash and magnesium. Fly ash up-to 18% by weight can be successfully added to commercially pure aluminum by stir casting route to produce composites.

- Toughness of the composites was resolute by using Izod and Charpy tests. As we increase the amount of ash the toughness value gradually increased up to some level i.e Sample 400gm aluminium, 15% fly ash with oil cooled but after this it diminishes.
- Hardness and tensile strength of the composites also presented the same results as like of toughness.

Future Scope: In future their wear properties can be growth for make sliding parts of automobile. The material is transferred back and forth several times during the sliding process and eventually produces particles of wear debris. When the applied load results in stresses higher than the fracture stress of fly ash particles, these particles lose their ability to support the load. Consequently, the aluminium matrix comes in direct contact with the counter face and large plastic strains are obligatoryon the contact surfaces of the pin.

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