Available online at http://www.journalijdr.com

International Journal of
DEVELOPMENT RESEARCH

IJDR

ISSN: 2230-9926

International Journal of Development Research
Vol. 3, Issue, 9, pp.001-004, September, 2013

Full Length Research Article

TRIBOLOGICAL PROPERTIES OF COPPER – FLYASH COMPOSITE

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ARTICLE INFO

Article History:
Received 10th June, 2013
Received in revised form
18th July, 2013
Accepted 05th July, 2013
Published online 19th September, 2013

Key words:
Copper,
Flyash,
Graphite,
Composite.

ABSTRACT

Copper and its alloys have found wide application in manufacture of bushes, bearings and high conductivity electrical contractors etc. This paper focuses the challenges and opportunities in the improvement of tribological characteristics of copper flyash composite and identifies low cost reinforcement material .Copper flyash mixtures with different weight percentages were prepared. Copper flyash composites improves strength, stiffness and wear resistance. The major drawback of these copper based composites are reduced conductivity and poor mach inability. These two factors are strongly influence the popularity of the developed copper based composites in several technological fields of applications. To overcome this soft phase graphite is used as a additional reinforcement to the copper flyash composite. Graphite being a solid lubricant can improve the mach inability of the composite. Furthermore, graphite possess excellent thermal and electrical conductivity thereby, can improve the conducting capability of copper composites.

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). 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. Fly ash is a finely divided powder generated as a solid waste in huge quantities during power generation in coal-based power plants. With rapid industrialization, it natural that, in coming years, power generation will continue to increase. At present, about 70% of total power generation in India is based on thermal power plants where sub-bituminous coal and/or lignite are burnt in huge amounts and, consequently, there is an estimated generation of about 80–90 million tonnes of fly ash per annum as the major solid waste (Kumar *et al*., 1999).

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In India, less than half of this is used as a raw material for concrete manufacturing and construction; the remaining is directly dumped on landfills or simply piled up. Only a small fraction is used in the development of high value products. Due to environmental regulations, new ways of utilizing fly ash are being explored in order to safeguard the environment and provide useful ways for its utilization and disposal.

There has been increasing interest in composites containing low density and low cost reinforcements. Among the various reinforcements used, fly ash is one of the most inexpensive and low density reinforcements available in large quantities as solid waste by product from combustion of coal in thermal power plants [6],[7],[8]. Fly ash particles are classified into two types, precipitator and cenosphere. Generally, the solid spherical particles of fly ash are called precipitator. The precipitator fly ash has a density ranges from 2.0 – 2.5 gm/cm^2. Hollow fly ash particles with a density less than 1.0 gm/cm^2 are called cenosphere fly ash. In recent years, copper based composites are gaining wide spread importance in several high tech application [1-3]. The mechanical properties of copper based conventional composites involving a single reinforcement have been studied [4]. Use of single reinforcement in copper may sometimes lead to the deterioration in the values of its physical properties. To overcome this concept of use of two different types of reinforcements are used in copper matrix [5]. The present investigation is aimed at producing copper fly ash composite using copper as matrix and fly ash as reinforcement. Pure copper is an element with F.C.C structure, excellent conductor, malleable and easy to cast into desired shapes. But this copper has to be alloyed with many other elements to effect minor changes in terms of the properties such as improving the tensile strength, hardness, mach inability etc [10]. The density and coefficient of thermal expansion of composite decrease, and their hardness and wear resistance increase as their fly ash content increases.

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 considerably, but all fly ash includes substantial amounts of silica (silicon dioxide, SiO2) (both amorphous and crystalline) and lime (calcium oxide, CaO). In general, fly ash consists of SiO_2, Al_2O_3, 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 with a specific surface area, typically between 250 and 600 m2/kg. The specific gravity of fly ash vary in the range of 0.6-2.8 gm/cc. Physical properties of fly ash mainly depend on the type of coal burned and the burning conditions. Class F fly ash is generally produced from burning high rank (containing high carbon content) coals such as anthracite and bituminous coals, whereas, Class C fly ash is produced from low rank coals. 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 cm-3 are called cenosphere fly ash. One common type of fly ash is generally composed of the crystalline compounds such as quartz, mullite and hematite, glassy compound such as silica glass, and other oxides. The precipitator fly ash, which has a density in the range 2.0–2.5 g cm^{-3} can improve various properties of selected matrix materials, including stiffness, strength, and wear resistance and reduce the density. Cenosphere fly ash, which consists of hollow fly ash particles, can be used for the synthesis of ultra-light composite materials due to its significantly low density, which is in the range 0.4–0.7 g cm^{-3}, compared with the densities of metal matrices, which is in the range of 1.6–11.0 g cm^{-3}. 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 flow able fill materials, in roadway/runway construction, in structural fill materials, as roofing granules, and in grouting. The largest application of fly ash is in the cement and concrete industry, though, creative new uses for fly ash are being actively sought like use of fly ash for the fabrication of Metal Matrix Composites (MMCs).

Chemical Composition and Classification of Fly Ash

Fly ash material solidifies while suspended in the exhaust gases and is collected by electrostatic precipitators or filter bags. Since the particles solidify while suspended in the exhaust gases, fly ash particles are generally spherical in shape and range in size from 1 µm to 100 µm. They consist mostly of silicon dioxide (SiO2), which is present in two forms: amorphous, which is rounded and smooth, and crystalline, which is sharp, pointed and hazardous; aluminium oxide (Al2O3) and iron oxide (Fe2O3). Fly ashes are generally highly heterogeneous, consisting of a mixture of glassy particles with various identifiable crystalline phases such as quartz, mullite, and various iron oxides.

Table 1

Component	Bituminous	Sub bituminous	Lignite
SiO2 (%)	20-60	40-60	15-45
Al2O3 (%)	5-35	20-30	20-25
Fe2O3 (%)	10-40	4-10	4-15
CaO (%)	1-12	5-30	15-40
LOI (%)	0-15	0-3	0-5

On the Basis of Chemical Composition

Two classes of fly ash are defined by ASTM C618: Class F fly ash and Class C fly ash. The chief difference between these classes is the amount of calcium, silica, alumina, and iron content in the ash. The chemical properties of the fly ash are largely influenced by the chemical content of the coal burned (i.e., anthracite, bituminous, and lignite).

Class F 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 contains less than 10% lime (CaO). Possessing 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.

Class C fly ash

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 generally contains more than 20% lime (CaO). Unlike Class F, self-cementing Class C fly ash does not require an activator. Alkali and sulfate (SO4) contents are generally higher in Class C fly ashes.

On the Basis of Size, Shape and Structure

Precipitator fly ash

It is spherical in nature, the spheres are solid and the density is in the range of 2.0–2.5 g cm^{-3}.

Cenosphere fly ash

It is also spherical in shape but these spheres are hollow, so the density of this kind of fly ash is very less as compared to the precipitator fly ash. Here density is less than 1 gm cm^{-3} (0.3-0.6 gm/cc)

Why Fly Ash?

- The preference to use fly ash as a filler or reinforcement in metal and polymer matrices is that fly ash is a byproduct of coal combustion, available in very large quantities (80 million tons per year) at very low costs since much of this is currently land filled. Currently, the use of manufactured glass microspheres has limited applications due mainly to their high cost of production. Therefore, the material costs of composites can be reduced significantly by incorporating fly ash into the matrices of polymers and metallic alloys. However, very little information 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. Cenosphere fly ash has a lower density than talc and calcium carbonate, but slightly higher than hollow glass .The cost of cenosphere is likely to be much lower than hollow glass. Cenosphere may turn out to be one of the lowest 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 insulating 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 mach inability, damping capacity, coefficient of friction etc. which are needed in various industries like automotive etc.
- As the production of Al is reduced by the utilization of fly ash. This reduces the generation of green house gases as they are produced during the bauxite processing and alumina reduction.

Chemical Reaction between Al and Fly Ash

The thermodynamic analysis indicates that there is possibility 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 8500 C, are likely to undergo chemical reactions. The experiments indicate that there is a progressive reduction between SiO2, Fe2O3 and mullite by Al and formation of Al2O3, Fe and Si. The wall of cenosphere fly ash particles progressive disintegrates into discrete particles into the reaction progress.

Experimental Details

Among discontinuous metal matrix composites, stir casting is generally accepted as a promising route, currently practiced commercially. Its advantages lie in its simplicity, flexibility and applicability to large quantity production. It is also attractive because conventional metal processing route to be used, and hence minimizes the final cost of the product.

Station), Vijayawada, India. The composition of fly ash samples were given in the Table1.

METHODOLOGY

Liquid state fabrication of Metal Matrix Composites involves incorporation of dispersed phase into a molten matrix metal, followed by its Solidification. In order to provide high level of mechanical properties of the composite, good interfacial bonding (wetting) between the dispersed phase and the liquid matrix should be obtained. Wetting improvement may be achieved by coating the dispersed phase particles (fibers). Proper coating not only reduces interfacial energy, but also prevents chemical interaction between the dispersed phase and the matrix. The simplest and the most cost effective method of liquid state fabrication is Stir Casting.

Stir casting

Stir casting is a liquid state method of composite material fabrication, in which a dispersed phase is mixed with a molten matrix metal by means of a mechanical stirring. Stir casting is characterized by the following features:

- Content of dispersed phase is limited (usually not more than 30% Vol.)
- Distribution of dispersed phase throughout the matrix is not perfectly homogeneous.
- Distribution of dispersed phase may be improved if the matrix is in semi solid condition.
- High viscosity of semi solid matrix material enables better mixing of the dispersed phase.

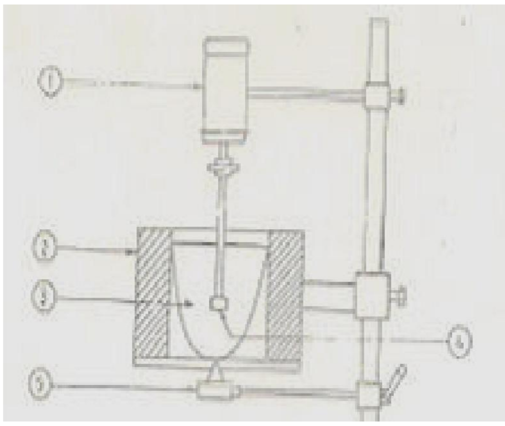

Figure.1: STIR Casting

1-Motor with stirring system, 2-Heating Furnace, 3-Crucible, 4-Stirring blade, 5-Plug.

Table 1. Chemical Composition of Fly ash by Wt %

SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	Loss on Ignition
58.41	30.40	8.44	2.75	1.3	1.53	1.0	1.98	2.4

Pure copper was melted using electrical furnace and preheated fly ash powders of 10%, 15%, 25% by weight were added to the molten metal. The composite melts were poured into preheated cast iron moulds of required size. The composite is tested in Universal testing machine for finding the tensile strength and hardness is find out by using Hardness testing machine. The microstructure of the specimen also observed. Fly ash particles used for this study were procured from thermal power plant of VTPS (Vijayawada Thermal Power

Copper fly ash composites are prepared by using stir casting process. All the melting was carried out in a graphite crucible in a electrical resistance furnace. The furnace temperature was first raised above the liquids temperature to melt the copper scraps completely (1250^0C) and was then cooled down just below the liquids to keep the slurry in a semi solid state. Fly ash particles were preheated at 650^0C for 3 to 4 hours. Addition of 1% titanium to increase the wettability of copper. Bottom pouring is preferred in copper fly ash composites.

During pouring of preheated fly ash particles into the crucible the stirrer is rotated continuously. After sufficient mixing was done, the composite slurry was reheated to a fully liquid state and then stirring is carried out for about 15 to 20 minutes at a normal stirring rate of 600 rpm. Pouring of the composite slurry has been carried out in the preheated cast iron moulds (200^0C to 300^0C) of required sizes.

RESULTS AND DISCUSSION

Morphology studies of copper fly ash composites

From the Figure 2 it reveals that a homogeneous distribution of the fly ash particles in the copper matrix, and this dispersion is increasing with increasing the amount of fly ash.

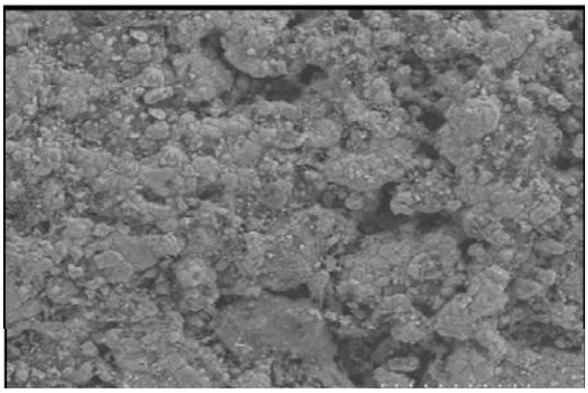

Figure 2: Morphology studies of copper fly ash composites

Mechanical properties of copper fly ash composites

Hardness Studies

The hardness of the material is a physical parameter indicating the ability of resisting local plastic deformation. As the amount fly ash increases the hardness of the composite also increases. This increase was observed from 250 VHN to 330 VHN.

Tensile Strength properties studies

The composite show higher loads than the unreinforced alloy, and this increase is more for higher the amount of fly ash. This indicates that the fly ash addition leads to improvement in the strength of the composite. The strength of the composite varies from 230 to 270 Mpa.

Conclusions

- Homogenous dispersion of fly ash particles are observed in copper matrix composite.
- The results of study suggested that with increase in composition of fly ash, an increase in hardness, strength.
- The best results has been obtained at 25 % weight fraction of 60 Microns fly ash particles.
- Graphite is used as a additional reinforcement to the copper fly ash composite can improve the Conductivity and mach inability.

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