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Industrial Importance of Aluminium-Fly Ash Composite and Its Application-A Review

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Abstract

The present investigation has been focused on utilization 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 produced with different percentages of reinforcing phase. Al-fly ash composite is electrically conductive and can be processed by ECM, Electrical Discharge Machining (EDM).

1. Introduction

The composite material can be defined as the system of material consisting of a mixture of combination of two or more micro constituents insoluble in each other and differing in form and or in material composition .These materials can be prepared by putting two or more dissimilar material in such way that they function mechanically as a single unit. The properties of such materials differ from those of their constituents. These materials may have a hard phase embedded in a soft phase or vice versa. Normally in the composite material have a hard phase in the soft ductile matrix where the hard phase act as a reinforcing agent increase the strength and modulus, and soft phase act as matrix material. The requirement for satisfying the above mentioned condition is a. The composite material has to be man-made b. The composite material must be a combination of at least two chemically distinct materials with an interface separating the components. c. The properties of composite should be three dimensionally combined.

The matrix in these composites is a ductile metals .These composites can be used at higher service temperature than their base metal counterparts. These reinforcements in these materials may improve specific stuffiness specific strength, abrasion resistance, creep resistance and dimensional stability. The MMCs is light in weight and resist wear and thermal distortion, so it mainly used in automobile industry. Metal matrix composites are much more expensive those PMCs and, therefore, their use is somewhat restricted.

One of the main objectives in producing CMCs is to increase the toughness. Ceramics materials are inherent resistant to oxidation and deterioration at elevated temperatures; were it not for their disposition to brittle fracture, some of these materials would be idea candidates for use in higher temperature and serve- stress applications, specifically for components in automobile an air craft gas turbine engines .The developments of CMCs has lagged behind mostly for remain reason, most processing route involve higher temperature and only employed with high temperature reinforcements [9].

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2. Aluminium matrix composites (AMCs)

In aluminium matrix composites (AMCs) one of the constituent is aluminium /aluminium alloy, which forms percolating network and is termed as matrix phase. The other constituent is embedded in this aluminium/aluminium alloy matrix and serves as reinforcement, which is usually non-metallic and commonly ceramic such as SiC and Al_2O_3. Properties of aluminium matrix composites (AMCs) can be tailored by varying the nature of constituents and their volume fraction. [15]

The major advantages of AMCs compared to unreinforced materials are as follows:

- Greater strength
- Improved stiffness
- Reduced density (weight)
- Improved high temperature properties
- Controlled thermal expansion coefficient
- Thermal/heat management
- Enhanced and tailored electrical performance
- Improved abrasion and wear resistance
- Control of mass (especially in reciprocating applications)
- Improved damping capabilities.

3. Particle reinforced aluminium matrix composites

Of all the AMCs, particle reinforced AMCs constitutes largest quantity of composites produced and utilised on volume and weight basis. PAMCs are produced by PM/ stir cast/melt infiltration/spraying/*in situ* processing techniques at industrial level. Particulates of SiC, Al_2O_3, TiC, TiB_2, and B_4C have been used as reinforcements. PAMCs have been successfully used as components in automotive, aerospace, opto-mechanical assemblies and thermal management. PAMCs are in use as fan exit guide vane (FEGV) in the gas turbine engine, as ventral fins and fuel access cover doors in military aircraft. PAMCs are also used as rotating blade sleeves in helicopters. Flight control hydraulic manifolds made of 40 vol% SiCp reinforced aluminium composites have been successfully used. The most notable large size and high volume use of PAMCs is in braking systems of trains and cars. Presently AMC brake discs are extensively used in European Railways and are in use in certain models of passenger cars in U.S.A. Potential automotive applications of PAMCs include valves, crankshafts, gear parts and suspension arms. Particle reinforced AMCs are in use as recreational products including golf club shaft and head, skating shoe, base ball shafts, horseshoes and bicycle frames. AMCs containing high volume fraction ceramic particles are being used as microprocessor lids and integrated heat sinks in electronic packaging. They are also in use as carrier plates and microwave housing.

4. Challenges and Opportunities

Several challenges must be overcome in order to intensify the engineering usage of AMCs. Design, research and product development efforts and business development skills are required to overcome these challenges. In this pursuit there is an imperative need to address the following issues.

- Science of primary processing of AMCs need to be understood more thoroughly, especially factors affecting the microstructural integrity including agglomerates in AMCs.
- There is need to improve the damage tolerant properties particularly fracture toughness and ductility in AMCs.
- Work should be done to produce high quality and low cost reinforcements from industrial wastes and by-products.
- Efforts should be made on the development of AMCs based on non-standard aluminium alloys as matrices.
- There is a greater need to classify different grades of AMCs based on property profile and manufacturing cost.
- There is an urgent need to develop simple, economical and portable non-destructive kits to quantify undesirable defects in AMCs.
- Secondary processing is an important issue in AMCs. Work must be initiated to develop simple and affordable joining techniques for AMCs. Development of less expensive tools for machining and cutting AMCs is of great necessity.
- Work must be done to develop re-cycling technology for AMCs.
- There must be more consortium/networking type approaches to share and document wealth of information on AMCs.

5. Aluminium- Fly ash Composite

Aluminium- fly ash composite is metal matrix dispersion strengthen composite in which soft and ductile aluminium matrix is strengthen by hard and brittle fly ash particles. Cast aluminum-fly ash composites, have the potential of being cost effective, ultra light composites, with significant applications. Such composites, if properly developed, can be applied for use in automotive components, machine parts and related industries. Aluminum is lightweight materials, when compared to iron and steel. However, they do not have the strength requirements necessary for several applications. Metal matrix composites manufactured by dispersing coal fly ash in common aluminum alloys improve mechanical properties such as hardness, stiffness, strength and abrasion resistance.

6. Fly Ash

The fly ash produced from the burning of pulverized coal in a coal-fired boiler is a fine-grained, powdery particulate material that is carried off in the flue gas and usually collected from the flue gas by means of electrostatic precipitators, bag houses, or mechanical collection devices such as cyclones. Thermal Power stations using pulverized coal or lignite as fuel generate large quantities of ash as a by-product. There are about 82 power plants in India, which form the major source of fly ash in the country. The properties of ash are a function of several variables such as coal source, degree of pulverization, design of boiler unit, loading and firing conditions, handling and storage methods. Thus, it is not surprising that a higher degree of variation can occur in ash, not only between power plants but within a single power plant also, but all fly ash includes substantial amounts of quartz, mullite, alumina, lime, hematite as major constituents and oxides of Mg, Ca, Na, K etc. as minor constituent. Fly ash particles are mostly spherical in shape with the specific gravity ranges from 0.3 to 2.5, while its specific surface area (measured by the Blaine air permeability method) may range from 170 to 1000 m^2/kg. Millions of tonnes of fly ash per year pose serious ecological problems. Fly ash is useful in many applications because it is a pozzolan, meaning it is a siliceous or alumino-siliceous material. Now a days fly ash is being used in several applications 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, aggregate, 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 MMCs. [22]

7. Classification of Fly Ash

(a} On the basis of chemical composition

Two major classes of fly ash are specified in ASTM C618 on the basis of their chemical composition resulting from the type of coal burned; these are designated Class F and Class C.

ASTM C618 defines two types of fly ash:

Class F has $SiO_2 + Al_2O_3 + Fe_2O_3$ minimum 70%

Class C has $SiO_2 + Al_2O_3 + Fe_2O_3$ minimum 50%

Class F are generally low-calcium fly ashes, total calcium typically ranges from 1 to 12 percent, mostly in the form of calcium hydroxide, calcium sulfate, and glassy components in combination with silica and alumina. In contrast, Class C fly ash may have reported calcium oxide contents as high as 30 to 40 percent. In general, Class C ashes are produced from burning sub-bituminous or lignite coals and Class F ashes produced from bituminous or anthracite coals. Another difference between Class F and Class C is that the amount of alkalis (combined sodium and potassium) and sulfates (SO_4) are generally higher in the Class C fly ashes than in the Class F fly ashes.

(b) On basis of size, shape and structure

(i) Precipitator fly ash

It is spherical in nature, the spheres are solid and the density is in the range of 2.0–2.5 gm /cm^3.

(ii) 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 (0.3-0.6gm/cc)

8. Why Fly Ash?

(a) The preference to given 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 cost and much of this is currently land filled. Currently, the use of manufactured glass microspheres has limited applications due to mainly 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. 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.

(b) The high electrical resistivity, low thermal conductivity and low density of fly-ash may be helpful for making a light weight insulating composites.

(c) Fly ash as a filler in Al casting reduces cost, decreases density and increase hardness, stiffness, wear and abrasion resistance. It also improves the machinability, damping capacity, coefficient of friction etc. which are needed in various industries like automotive etc.

(d) 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 reduct.

9. Advantages of Using Ash Composite

The significance of developing and marketing ash composite can be fully understood only if we consider the overall benefit to various industries and to the environment. The process of developing an ash alloy matrix with excellent properties is very involved, expensive and lengthy. The following are a few of the benefits that will have a significant impact on the community: [23]

1. Economics: Ash composites are at least 10-30% lower in cost than other alloys available in the market. Hence foundries and auto part manufacturers can potentially realize significant savings which can be shared with consumers.

2. Reduced Energy Consumption: With a projected annual displacement of 225,000 tons of aluminum with ash, the savings in energy costs for aluminum production is about $156 million annually.

3. Availability of Lightweight Material: The auto industry has a goal to reduce vehicle weight. Ash alloys are significantly lighter when compared to steel.

4. Improved Gas Mileage: Due to the projected significant weight reductions, the gas mileage of U. S. vehicles will improve and the savings will be significant. The Department of Energy's Light-Weight Materials Program has predicted that a 25% weight reduction of current vehicles would result in a 13% (750,000 barrels/day) reduction in U.S. gas consumption.

5. Avoided Ash Disposal Cost: Electric utilities generate millions of tons of coal fly ash per year, which are landfilled. If fly ash can be sold as metal matrix filler, utilities would avoid disposal costs and simultaneously generate revenue from the sale of ash. The anticipated market value of processed fly ash is $100/ton.

6. Reduced Greenhouse Gases: Greenhouse gases are produced during the two stages of aluminum production; bauxite processing and alumina reduction. Carbon dioxide (CO2) and perfluorocarbons (PFCs) are generated in significant amounts during these processes. Decreasing the production of aluminum or other metals by fly ash substitution will significantly reduce the production of these gases. CO2 emissions would also be reduced by approximately 101 million tons per year.

7. U.S. Competitiveness: The U.S. auto parts manufacturers are losing market share to overseas competitors who benefit from low-cost labor. The competitive edge of the United States is its research and development facilities and technical expertise. Development and commercial use of a superior ash composite matrix at less than half the cost of conventional materials can boost the competitive edge of U.S. parts manufacturers. These benefits are not limited to the automotive industry. The commercial applications of lighter weight materials, if properly exploited, can benefit foundries, manufacturers, transportation, construction, electrical and consumer goods industries.

References

[1.] SP Dwivedi, Sudhir Kumar, Ajay Kumar, Effect of turning parameters on surface roughness of A356/5% SiC composite produced by electromagnetic stir casting, Journal of Mechanical Science and Technology, 26 (12), 2012, 3973~3979.

[2.] Shashi Prakash Dwivedi, Satpal Sharma, Raghvendra Kumar Mishra, Microstructure and Mechanical Properties of A356/SiC Composites Fabricated by Electromagnetic Stir Casting, Procedia Materials Science 6,2014, 1524 – 1532.

[3.] Shashi Prakash Dwivedi, Satpal Sharma, Raghvendra Kumar Mishra, Microstructure and mechanical behavior of A356/SiC/Fly-ash hybrid composites produced by electromagnetic stir casting, J Braz. Soc. Mech. Sci. Eng., 37, 2015, 57–67.

[4.] NCh Kaushik, RN Rao, The effect of wear parameters and heattreatment on two body abrasive wear of Al–SiC–Gr hybrid composites, Tribology International, 96, 2016, 184–190.

[5.] Shashi Prakash Dwivedi, Satpal Sharma, Raghvendra Kumar Mishra, Effects of roller burnishing process parameters on surface roughness of A356/5%SiC composite using response surface methodology, Adv. Manuf., 2, 2014, 303–317.

[6.] Patricio Toro, Raúl Quijada, Mehrdad Yazdani-Pedram, José Luis Arias, Eggshell, a new bio-filler for polypropylene composites, Materials Letters, 61, 2007, 4347–4350.

[7.] SB Hassan, VS. Aigbodion, Effects of eggshell on the microstructures and properties of Al–Cu–

Mg/eggshell particulate composites, Journal of King Saud University – Engineering Sciences, 27, 2015, 49–56.

[8.] Amba Chaithanyasai, Pragnya Rani Vakchore, V Umasankar, The micro structural and mechanical property study of effects of EGG SHELL particles on the Aluminum 6061, Procedia Engineering, 97, 2014, 961 – 967.

[9.] S Basavarajappa, G Chandramohan, Arjun Mahadevan, Mukundan Thangavelu, R Subramanian, P Gopalakrishnan, Influence of sliding speed on the dry sliding wear behaviour and the subsurface deformation on hybrid metal matrix composite, Wear, 262, 2007, 1007–1012.

[10.] Du Jun, Liu Yaohui, Yu Sirong, Li Wenfang, Effect of heat-treatment on friction and wear properties of Al2O3 and carbon short fibres reinforced AlSi12CuMgNi hybrid composites, Wear, 262, 2007, 1289–1295.

[11.] A. Arun premnath, T. Alwarsamy, T. Abhinav, C. Adithya Krishnakant, Surface roughness prediction by response surface methodology in milling of hybrid aluminium composites" Procedia Engineering, 38, 2012, 745-752.

[12.] TS Mahesh Babu, MS Aldrin Sugin, N Muthukrishnan, Investigation on the characterstics of surface quality on machining of hybrid metal matrix composite (Al-SiC-B_4C), Procedia Engineering, 38, 2012, 2617-2624.