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DEVELOPMENT AND CHARACTERIZATION OF ALUMINIUM CENOSPHERE METAL MATRIX COMPOSITE

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ABSTACT: The present investigation is focused on optimum Fly ash Chemosphere particles into Aluminum Matrix to produce Aluminum Chemosphere Metal Matrix composite (MMC) to achieve maximum strength and minimum weight and cost. The parameter like weight percentage, particle size, and wettability are considered. Stir casting manufacturing setup is fabricated with temperature controller and speed controller. Preliminary chemical analysis reveals that considerable increase in Si, Mg, Fe and Zn in the composite, which will lead to an increase in wear resistance and decrease in co-efficient of friction. The reinforcements added to Aluminum alloy will lead to variation in properties. The content and size of the reinforcement influences the properties of composites
Keywords: metal matrix composite, aluminum, chemosphere

1. 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.

Composite materials are normally comprised of two components. The main part of the composite is known as the matrix phase. Inside the matrix is a reinforcing phase. Matrix Phase has the following characteristics

» The primary phase, having a continuous character.
» Usually more ductile and less hard phase.
» Holds the reinforcing phase and shares a load with it.

Reinforcing Phase has the following characteristics.

» Second phase (or phases) is embedded in the matrix in a discontinuous form.
» Usually stronger than the matrix, therefore it is sometimes called reinforcing phase.

The matrix in these composites is a ductile material. This Metal Matrix Composites (MMC) can be used at higher service temperature than their base metal counterpart's. These reinforcements in these materials may improve specific stiffness specific strength, abrasion resistance, creep resistance and dimensional stability [1]. The MMCs is light in weight and resist wear and thermal distortion so it mainly used in automobile industry. [2]

One the basis of reinforcement metal matrix composites can be classified into Particle reinforced composite, Fiber reinforced composite, Laminate composite. Particulate reinforcements have

dimensions that are approximately equal in all directions. The shape of the reinforcing particles may be spherical, cubic, platelet or any regular or irregular geometry. Particle reinforced can be subcategorized into two types Large particle composite and Dispersion strengthened composite.
The term large is used to indicate that particle–matrix interactions cannot be treated as on the atomic or molecular level, rather on continuum mechanics level. For most of these the particulate phase is harder and thicker than the matrix. These reinforcing particles tend to restrain movement of the matrix phase in the vicinity of each particle. In essence the matrix transfers some of the stress to the particles which bear a fraction of the load. The degree of reinforcement or improvement of mechanical behavior depends on strong bonding at the matrix particle interface.
In dispersion strengthened composite, particles are normally much smaller with diameters between 5 to 500 microns. Particle – matrix interactions that lead to strengthening occur on the atomic or molecular level. The mechanism of strengthening is similar to that for precipitation hardening. Whereas the matrix bears the major portion of an applied load, the small dispersed particles hinder or impede the motion of dislocations. Thus plastic deformation is restricted such that yield and tensile strength as well as hardness improve.
With particle reinforcements, metal matrix composites exhibit isotropic properties. Aluminum alloys with various reinforcements have been considered for applications in automotive components. The present investigation has been focused on utilization of waste fly ash particle in useful manner by dispersing it in Aluminum matrix to produce composite. In the present work, fly ash particle which mainly consists of refractory oxides like silica, alumina and iron oxides will be used as the reinforcing phase and to increase the wettability magnesium is added. Further these composites will be characterized with help of optical microscopy.

2. ALUMINIUM ALLOY AND THEIR PRPOERTIES

Commercial aluminum alloys can be classified into wrought heat treatable alloys, Wrought non-heat-treatable alloys and Casting alloys. Wrought heat treatable aluminum alloys are the most common alloys in the aluminum family. Al- Mg-Si (6000), Al-Cu-Mg (2000), and Al-Zn- Mg (7000), are some of the widely used Al alloys, which require heat treatment to develop high strength through precipitation hardening. These alloys offer a wide range of strength and ductility. They have been used extensively in Automobile and Aerospace industries and have also been used for MMC development [3]

3. FLY ASH PROPERTIES

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 amount of silica (SiO_2) (both morphous and crystalline) and lime (calcium oxide, CaO). In general fly ash consists of SiO_2, Al_2O_3, and Fe_2O_3 as major constituents of oxides of Mg, Ca, Na, etc. as minor constituent. Fly ash particle are mostly spherical in shape and range from less than 1μm to 500μm with the specific surface area, typically between 250 and 600 meter square per kg, the specific gravity of fly ash vary in the range of 0.6-2.8 gm/cc. Coal fly ash has many uses including as a cement additive, in masonry blocks, as a concrete admixture, as a material in light weight alloys, as a concrete aggregate, in flowable fill materials, in roadway/runway construction, in structural field material, as a roofing granules and in grouting. The largest application of fly ash in the cement and concrete industry, creative new uses for fly ash are being actively sought like use of fly ash for the fabrication of MMC.
On the basis of size, shape and structure flay ash can be classified into Precipitator Fly ash and Chemosphere Fly ash [4]. Precipitator fly ash is spherical in nature, the spheres are solid and the density in the range of 2.0-2.5gm cm-3. Whereas Chemosphere fly ash contains hollower Chemosphere particle which can be collected from the collection pond. It is also spherical in shape but these spheres are hollows, so the density of this kind of fly ash is very less as compared to the precipitator fly ash (2-2.8gm/cc). Here density is less than 1gm cm-3 (0.3-0.6gm/cc).In our present study Chemosphere fly ash is selected for particle reinforcement in aluminum alloy because of the following reasons.

a. Chemosphere has a lower density than calcium carbonate and slightly higher than hollow glass. The cost of Chemosphere is likely to be much lower than hollow glass. Chemosphere will turn out to be one of the lower cost fillers in terms of the cost per volume. Chemosphere 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 various industries like automotives, aeronautics.etc.

b. The high electrical resistivity, low thermal conductivity and low thermal density of Chemosphere may be helpful for making a light weight insulating composite
c. As the production of Al is reduced by the utilization of Chemosphere, it reduces the generation of green house gases as they are produced during the bauxite processing and alumina reduction.

4. FABRICATION TECHNIQUES FOR METAL MATRIX COMPOSITES

A number of composites fabrication techniques have been developed that can be placed categorized into Powder metallurgy and liquid metallurgy. Powder blending followed by consolidation (PM processing) diffusion bonding and vapor deposition techniques come under solid state processing. Powder metallurgy techniques offer the following two advantages over liquid metallurgy techniques for fabricating MMCs.

i. Lower temperatures can be used during preparation of a PM-based composite compared with preparation of a liquid metallurgy based composite. The result is lesser interaction between the matrix and the reinforcement when using the PM technique. By minimizing undesirable inter-facial reactions, improved mechanical properties are obtained.
ii. In some cases, PM techniques will permit the preparation of composites that cannot be prepared by the liquid metallurgy. For instance, fibbers or particles of silicon carbide will dissolve in melts of several metals like titanium and such composites will be difficult to prepare using liquid metallurgy techniques.

Liquid state processes include stir casting or compo casting, infiltration, spray casting and in situ (reactive) processing. The selection of the processing route depends on many factors including type and level of reinforcement loading and the degree of micro structural integrity desired.

5. STIR CASTING

This involves incorporation of ceramic particulate into liquid aluminum alloy melt. The simplest and most commercially used technique is known as vortex technique or stir casting technique. Vortex technique involves the introduction of pre-treated ceramic particles into the vortex of molten alloy created by the rotating impeller. Lloyd (1999) has reports that vortex mixing techniques for the preparation of ceramic particle dispersed aluminum matrix composite was originally developed by Surappa and Rohatgi (1981) at the Indian institute of science Bangalore. Subsequently several aluminum company of the refined and modified the process which are currently employed to manufacture a variety of aluminum metal matrix composite on commercial scale.

The vortex methods one of the better known approaches used to create and maintain a good distribution of the reinforcement material in the matrix alloy in this method, after the matrix material is melted, it is stirred vigorously to form a vortex at the surface of the melt, and the reinforcement material is then introduced at the side of the vortex. The stirring is continued for a few minutes before the slurry is cast ,there are different design of mechanical stirrers .Among them ,the turbine stirrer is quite popular .During stir casting of the synthesis of composites ,stirring helps in two ways.

» transferring particle into the liquid metals
» maintain the particle in the state of suspension

6. EXPERIMENTATION

Aluminum 6063 is chosen as matrix material due to its very good property compared to other aluminum alloys and also its extensive usage in automobile industry. Aluminum is bought from the market in wire form. To check the aluminum purity spark test specimen was made and tested in SiTarc (Small industries testing and research centre) Coimbatore. Spark analyzer testing equipment was used to conduct chemical composition test. The result of the chemical analysis test is given in the following Table 1.

Table 1. Chemical composition of 6063 aluminum alloy

Chemical composition of 6063 aluminum alloy [%]												
Si	Fe	Cu	Mn	Mg	Sn	Na	Ca	B	Zr	Sb	Ga	P
0.42	0.28	0.034	0.07	0.27	0.003	0.0002	0.0002	0.003	0.002	0.01	0.012	0.003
Li	Al	Zn	Ti	Ni	Pb	V	Be	Co	Cd	Cr	Sr	
NIL	98.68	0.055	0.016	0.008	0.016	0.01	0.00004	0.008	0.0003	0.006	0.0003	

A. PARTICLE SIZE OF CENOSPHERE

The size, density, type of reinforcing particles and its distribution have a pronounced effect on the properties of particulate composite. The size of Chemosphere particles vary from 5-500 micron. The size range of the Chemosphere particles indicate that the composite prepared can be considered as dispersion strengthened as well as particle reinforced composite. Dispersion strengthening is due to the incorporation of very fine particles, which help to restrict the movement of dislocations, whereas in particle strengthening, load sharing is the mechanism.

B. HAND SIEVE

Chemosphere size is an important factor to the strength of the composite, so present study includes the different size of Chemosphere in the composite. Particles are separated in to different size range using hand sieves. Most of the Chemosphere bought are falling in to 100-200 micron size. Hand sieves are made up of brass material to avoid the wear while sieving the Chemosphere. Standard sieves used in this study are shown in the Figure 1.

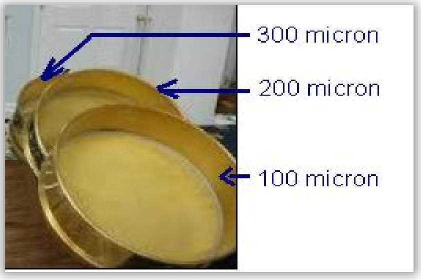

Figure 1. Hand Sieve

C. STIRRER

A stirrer was fabricated to mix the molten aluminum, magnesium and fly ash. The stirrer consists of a 0.25 HP motor, a cast iron turbine type impeller, Aluminum alloy pulley, Stainless steel hollow impeller shaft, regulator to control speed of the motor and a stand to hold the stirrer assembly in place.

D. TEMPERATURE CONTROLLER

Temperature controller consists of a number of components which are shown in figure. Relay on/off indicator which is in green color, Main temperature controller on/off indicator which is in yellow color, Main on/off switch, temperature setting, thermocouple and temperature display. Thermocouple is used to measure the temperature from the furnace. And measured temperature will be displayed using temperature display unit. Furnace temperature can be achieved by setting the required temperature in the display unit. Once the required temperature is reached then the output power to the heating coil will be stopped by automatic relay off.

E. FURNACE

The main purpose of the furnace is to heat the aluminum for the required temperature. Furnace consists of heating coil, insulation and insulated cap. Dimensions of the furnace are diameter 6 inch, height 6 inch which is surrounded by heating coil and 2 inch thickness insulation. Handle is placed to the furnace for easy handling even at high temperature. The furnace cap has two holes in it. One is to pour the Chemosphere and another one is for impeller shaft. Furnace cap can be clamped with bottom part while furnace in operation to avoid the spaying of molten metal out as well as to achieve the proper insulation. Furnace used in this work is shown in the figure 2.

Figure 2. Furnace

F. PRE HEATER AND TOTAL STIR CASTING SETUP

It is similar to the furnace with simple modifications. Its main purpose is to pre heat the Chemosphere particle for certain temperature for the particular time. Preheating is necessary to remove the moisture content present in the Chemosphere and also to accommodate the sudden temperature change in Chemosphere while adding to the molten aluminum.

7. RESULTS AND DISCUSSIONS

The aluminum fly ash metal matrix composite was prepared by stir casting method. For this, 1kg of commercial 6063 aluminum alloy and desired amount of Chemosphere particles are taken. The volume % of Chemosphere particles used was 10%. Aluminum alloy 6063 was melted in a resistance furnace. The melt temperature was raised up to 730°C, then the melt was stirred with the help of a stirrer .The stirring was maintained between 5 to 7 min at an impeller speed of 200 rpm. The melt temperature was maintained at 700°C during addition of Chemosphere particles. The dispersion of Chemosphere was achieved by the vortex method. The melt with reinforced particulates were poured into sand mould and allowed to solidify. The composite was made at different amount of Chemosphere with different particles size as stated earlier.

After the casting was solidified and cut into required specimen size chemical composition of Aluminum Chemosphere composite was tested in SiTarc (Small industries testing and research centre) Coimbatore. Spark analyzer testing equipment was used to conduct chemical composition test. The result of the chemical analysis test is given in the following Table 2.

Table 2. Chemical Composition of Aluminum Chemosphere Metal Matrix Composite

Chemical Composition of Aluminum Chemosphere Metal Matrix Composite, [%]												
Si	Fe	Cu	Mn	Mg	Sn	Na	Ca	B	Zr	Sb	Ga	P
3.93	0.60	0.037	0.063	1.35	0.005	0.002	0.0002	0.0002	0.001	0.002	0.012	0.002
	Al	Zn	Ti	Ni	Pb	V	Be	Co	Cd	Cr	Sr	
NIL	93.69	0.10	0.035	0.035	0.03	0.012	0.0001	0.001	0.0003	0.011	0.0007	

Chemical composition Analysis for Aluminum Chemosphere Metal Matrix Composite were conducted using spark analyzer testing equipment at SiTarc (Small industries testing and research centre) Coimbatore. The result of the chemical analysis test for the pure Aluminum 6065 alloy is listed in the Table 1 and also the result of the chemical analysis test for Aluminum Chemosphere composite specimen is listed in the Table 2. The major changes in the alloying elements are listed in the following Table 3 because of the mixing of Chemosphere along with Aluminum alloy 6063.

Table 3. Major changes in chemical composition of aluminum chemosphere alloy when compared to 6063 aluminum alloy

Si [%]		Fe [%]		Mg [%]		Cr [%]		Ni [%]		Al [%]	
(PA)	(AC)	(PA)	(AC)	(PA)	(AC)	(PA)	(AC)	(PA)	(AC)	(PA)	(AC)
0.42	3.93	0.28	0.60	0.27	1.35	0.006	0.011	0.008	0.035	98.68	93.69

Hardness value for Aluminum Alloy 6063 (ALCOA 6063-Extruded Aluminum alloy) was referred from American Society of Metals (ASM) International and the hardness value of Chemosphere mixed with Aluminum Alloy is mentioned in the table 4. It is inferred that the reason for not much improvement in the hardness value for 15 % mixing is that the hardness was taken where the Chemosphere particle was not presented. Also preliminary Scanning Electron Microscope (SEM) study reveals that the Chemosphere was homogeneously distributed over the entire area of Aluminum 6063 without any agglomeration.

Table 4. Hardness value of aluminum chemosphere metal matrix composite

CE %	Brinell Hardness (BHN)	Vickers Hardness (VHN) / 100 g load
6063 + 5 % CE	60	62
6063 + 10 % CE	80	81
6063 + 15 % CE	76	78

CE = Chemosphere percentage

8. CONCLUSIONS

With reference to many literature surveys the following are the conclusions from the above experiment.

1. From the above experimental study we can conclude that the residues generated during the combustion of coal (Fly Ash-Chemosphere) can be effectively utilized for particulate reinforcement in Aluminum Metal Matrix.
2. With the identification of Fly Ash-Chemosphere geotechnical characteristics it is clear that it can be used as an energy efficient particulate reinforcement to form a Metal Matrix Composite
3. From the above experimental study result it is clear that there is a considerable increase in Si, Fe, Mg, Cr, Ni, Zn and Ti.
4. With reference to many literature surveys it is clear that because of the increase in the above mentioned element composition there will be a considerable improvement in hardness and wear characteristics [8] of this Aluminum Chemosphere Metal Matrix composite.

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