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STRUCTURE PROPERTY CORRELATION AND WEAR BEHAVIOR OF NICKEL COATED FLY ASH CENOSPHERES - ALUMINIUM COMPOSITE

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ABSTRACT

The need for lightweight materials with desirable properties such as high strength and improved stiffness for automotive and aerospace application have generated considerable interest to develop aluminium based metal matrix composites. Aluminium matrix composites (AMC's) have different and often improved properties as compared to their monolithic metal counterparts. In India, majority of the coal fired thermal power plants still resort to wet slurry disposal of ash. At the ash pond, the lightweight floating particles termed cenospheres are harvested, which have been found to be composite particles with excellent physical, chemical, morphological and mineralogical characteristics. This paper discusses the development of nickel coated fly ash cenosphere particles by the autocatalytic deposition and its use as a reinforcing particulate composite in the casting of aluminium metal matrix composite. Based on the metal, reinforcing phases, respective ratios and processing methodology, nickel coated fly ash cenospheres – aluminium composite with better features in terms of contact wear resistance, hardness have been developed. The paper also brings out the structure – property correlation of nickel coated cenosphere – aluminium metal matrix composite.

Keywords: *Nickel coated cenospheres, Aluminium Metal Matrix Composites, Sliding Wear and Microstructure Studies.*

1. Introduction

Metal Matrix composites are engineered combinations of two or more materials in which tailored properties are achieved by systematic combinations of different constituents [1]. Several researchers have reported that particluate reinforced composites exhibit superior mechanical properties [2]. Particulates such as SiC, TiC, TiB_2, and fly ash have been used to reinforce aluminium alloys to improve their mechanical properties and wear resistance [3-8]. In the recent years the use of fly ash as reinforcement in aluminium alloys has been reported to improve the mechanical properties of the alloy systems in view of its avaliability as a low cost waste material [9]. K V mahendra et.al have reported a higher tensile strength and hardness for Al 4.5% Copper alloy fly ash composites [10]. M Ramachandra et. al in a study on the mechanical properties of hypo eutectic fly ash composites, have reported that an increase in hardness and tensile strength [11]. Hyper-eutectic Al-Si based composites such as A356 (A1, 7Si) that contain aluminium particles or Sic particles are used in the fabrication of automotive engine components [12].

Wear resistance and operating properties of aluminium cast diesel pistons are enhanced by the use of aluminium-based composite piston ring inserts. These composite inserts are reinforced with whiskers or a combination of these whiskers (12 vol.%) and carbon fibres (9 vol.%). Aluminium-based composites have also been considered as substitute materials for use in the fabrication of brake rotors, pistons, cylinder liners and cylinder heads. A comprehensive review of the current and potential application for cast aluminium matrix composites in the automotive industry has been provided by Rohatgi. [12]. Metal-matrix composites exhibit significant increase in stiffness and mechanical strength compared to matrix alloys, but often suffer from lower ductility aud inferior fracture toughness. MMCs exhibit the ability to withstand high tensile and compressive stresses by the transfer and distribution of the applied load from the ductile matrix to the reinforcement phase. This load transfer is possible due only to the existence of an interfacial bond between the particulate reinforcement and the matrix [13].Fly ash cenospheres are generated in large amounts as a by-product in thermal power plants and pose major disposal problems. Fly ash cenosphere particles are

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unique, property stable, non-toxic, non-metallic hollow micro-particles. Due to the unique hollow structure and physical mechanics properties, fly ash cenosphere particles have been dispersed in different matrices, such as polyester resins, cement, and nickel for producing composite materials in the bulk and coating forms for a variety of industrial applications.

Fly ash cenosphere particles are a non-conducting ceramic materials, the desired magnetizability may be imparted to these particles by coating ferrite on their surface. Due to their low density, these ferrite- coated fly-ash cenospheres may find applications as microwave absorbing materials [14-19].

A detailed study of the existing literature reveals that very few systematic investigations have been carried out to study the influence of fly ash cenospheres on the wear properies. The existing literature also does not provide any data on the use of electroless metal coated cenospheres in the preparation of composites.

2. Experimental Details

The base matrix and the reinforcing phase for the present studies selected were Al6061, and coated cenospheres of size 100 μm. The chemical composition of the selected base matrix is shown in Table 1. The procedure of electroless coating is described elsewhere [20].

The liquid metallurgy technique with optimum care was taken and standard procedure was followed to obtain the cast composites. The particles were preheated before being introduced into the vortex and stirring of the molten composite were accomplished for 10 minutes at 400 rpm stirrer speed. Pouring temperatures adopted were 720^0C. The cylinders of 22mm X 210mm cast composites of Al6061 and coated cenospheres were obtained.

The test for hardness (ASTM E-10-08), and wear resistance (ASTM G – 99) of the prepared cast matrix and their composite were carried out as per ASTM standards. Shimadzu Japan make Brinell micro hardness tester served the purpose of measurement of hardness. Carefully polished and mirror finished specimens were examined under a microscope to obtain microphotographs. Ducom make computerized pin on disc wear testing machine with test material as pin and high carbon EN31 steel (HRC60) as counter-surface, equipped with LVDT and digital display system served to record the wear height loss in microns.

3. Results and Discussions

After the samples are cast and then machined as discussed in the previous section, the following sample designations have been assigned.

Table: 1 Sample Designations

Sample Designation	Chemical Composition
Al6061-Ni - Ce-0	100 % Aluminium, 0 % Cenosphere
Al6061- Ni - Ce- 2	98 % Aluminium, 2 % Coated Cenosphere
Al6061- Ni - Ce- 4	96 % Aluminium, 4 % Coated Cenosphere
Al6061 – Ni - Ce – 6	94 % Aluminium, 6 % Coated Cenosphere
Al6061- Ni - Ce- 8	92 % Aluminium, 8 % Coated Cenosphere
Al6061 – Ni - Ce – 10	90 % Aluminium, 10 % Coated Cenosphere

3.1 Hardness test results - BHN

The samples are then tested for hardness (BHN) values. It is seen from the table (Table No2. and the graph (Fig No1.) that the hardness values have shown a significant increase. This is largely due to the fact that the cenosphere forms a hard reinforcement in the aluminium matrix. This is due to the physical and chemical nature of the cenospheres.

The cenospheres are extremely hard (hardness value of 5-7 on the mhos scale). This is the primary reason for the gradual increase in hardness when compared to the pure aluminium samples. This fact is also attributed to the homogeneous distribution of the cenospheres in the matrix as seen in the microstructure Fig. 3.

Table 2: Hardness of Samples

Sl. No.	Sample designation	Hardness (BHN)
1	Al6061- Ni - Ce- 0	30
2	Al6061- Ni - Ce- 2	32
3	Al6061- Ni - Ce- 4	36
4	Al6061- Ni - Ce- 6	39
5	Al6061- Ni - Ce- 8	41
6	Al6061- Ni - Ce- 10	43

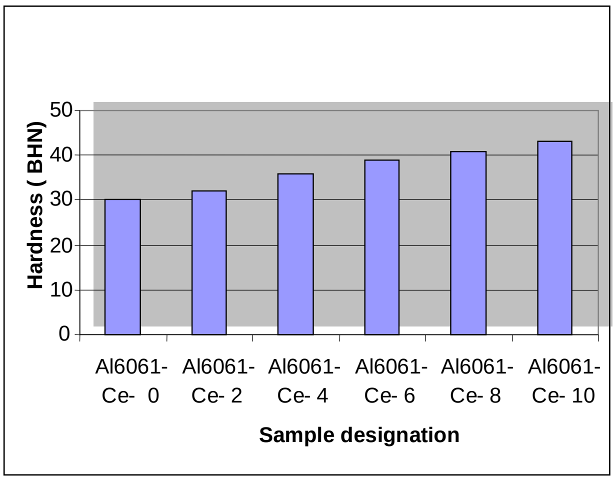

Fig. 1 BHN v/s Sample Designation

3.2 Microstructure analysis

Fig. 2 Microstructure of Al 6061- Ni-Ce-0% (400 x)

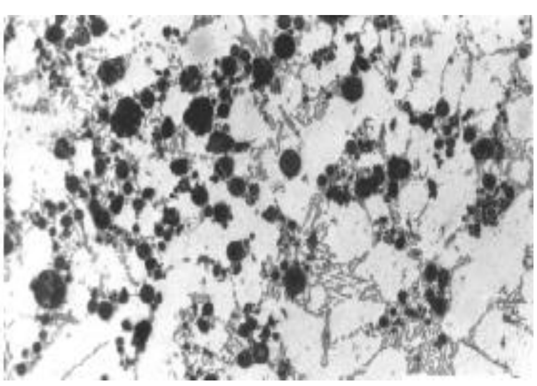

Fig. 3 Microstructure of Al 6061-Ni-Ce-10% (400 x)

It can be seen from the microphotographs that there is a homogeneous distribution of cenospheres in samples, hence uniform mechanical properties throughout the specimens.

3.3 Wear tests

Pin on disc sliding wear test was conducted on all the six samples and the weight loss is as computed.

Table 3: Weight Loss of Samples

Load in Kgs	Weight Loss in gms					
	0 %	2 %	4 %	6 %	8 %	10 %
1.0	0.73	0.67	0.64	0.61	0.58	0.55
1.5	0.81	0.78	0.73	0.70	0.69	0.65
2.0	0.85	0.84	0.81	0.77	0.75	0.70

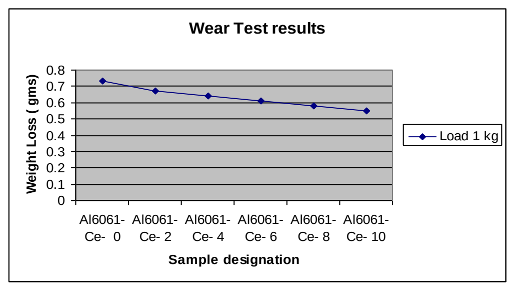

Fig. 4 Wear Test Result for 1 kg Load

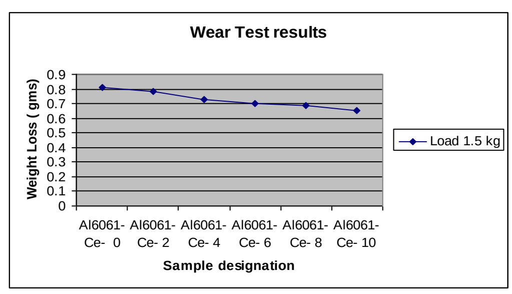

Fig. 5 Wear Test Result for 1.5 kg Load

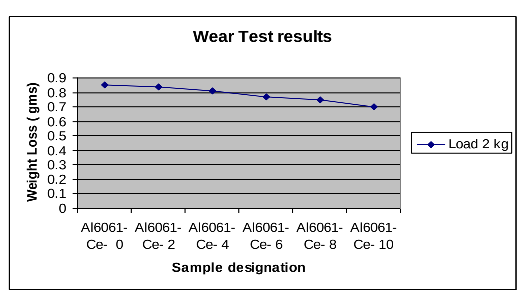

Fig. 6 Wear Test Results for 2 kg Load

It is seen from the graph (Fig 4, 5 and 6) and the table (Table No. 3) that the weight loss for the samples with 2 kg loads in comparison with the unreinforced samples is minimum. This is due to the presence of hard reinforcement in the form of cenospheres. The hardness of the cenosphere particles and the nickel coating adds on to the hardness of the aluminium composite and thereby improves the wear resistance.

4. Conclusions

i. Sample having 10% of nickel coated cenospheres have shown 30 % improvement in hardness
ii. The increase in hardness has been attributed to the fact, due to the presence of a hard reinforcement of Nickel coated cenospheres.
iii. The microstructure studies also confirm the presence of a hard reinforcement homogeneously distributed in the matrix.
iv. Resistance to wear has also shown a significant improvement in the samples with Nickel coated cenospheres.
v. The composite prepared finds very good application in replacement of automobile parts since these composites have a higher wear resistance and hence a higher life when compared to pure aluminium components.

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