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Structure Property Correlation and Evaluation of Tensile Properties of Cenosphere Aluminium Composites

Prashanth T*, Narasimha Murthy K* and Umesh C K**

The automobile and aerospace industries relenting passion to enhance the performance of commercial and military applications is constantly driving the development of improved high performance structural materials. Composite materials are one such class of materials that play a significant role in current and future aerospace applications. Composite materials are particularly attractive to both automobile and aerospace applications because of their exceptional strength and stiffness to density ratios and superior mechanical properties. Cenospheres are hollow alumino-silicate microspheres from fly ash of thermal power stations and are a valuable industrial product due to successful combination of their technical and commercial parameters and can be used as a creation of functional materials. This paper discusses the use of cenospheres as reinforcement in the casting of aluminum metal matrix composite. Based on the metal, reinforcing phases, respective ratios, fly ash cenospheres – aluminum composite with better features in terms of density, strength and hardness have been developed.

Keywords: *Aluminium metal matrix composites, Cenospheres, Ultimate tensile strength, Structure property correlation.*

1.0 INTRODUCTION

Particle reinforced Al matrix composites are emerging out as potential materials to replace conventional alloys/metals. These metal matrix composites (MMCs) find extensive applications in many engineering activities because of their lightweight, high stiffness and high specific strength. They also offer better tribological properties, controlled thermal conductivity, wear resistance of all the aluminum alloys, 6061 is quite popular choice as a matrix material to prepare metal matrix composites owing to its better formability characteristics and option of modification of the strength of composites by adopting optimal heat treatment [1]. Al alloy Al 6061 is widely used in numerous engineering applications including transport and construction where superior mechanical properties such as tensile strength, hardness, etc. are essentially required.

Fly ash particles are potential discontinuous dispersoids used in metal matrix composites, since they are low-cost and low-density reinforcement available in large quantities as a waste by-product in thermal power plants. Fly ash is a particulate waste material formed as a result of coal combustion in power plants. The use of fly ash as a filler or reinforcement for aluminum alloys, called Metal Matrix Composites (MMC's), is, therefore, very desirable from an environmental standpoint. Fly ash forms at temperatures in the range of 920–1200ºC and is collected as precipitator

*Department of Mechanical Engineering, PES Institute of Technology, Bangalore. E-mail: prash_t@yahoo.com
**Department of Mechanical Engineering, UVCE, Bangalore.

ash (solid particles) and cenospheres (hollow microspheres) that float on collection ponds [2,3]. Cenosphere has a low density of about 0.6 g cm^{-3}, and can be used for the synthesis of ultra-light composites materials, whereas precipitator fly ash has a density in the range of 2.0–2.5 g cm^{-3}. It can improve various properties of selected matrix materials, including stiffness, strength, and wear resistance [4–6].

Aluminium-fly ash composites offer many potential applications particularly for internal combustion engine pistons and brake rotors due to their density and high mechanical properties. From both an economical and environmental standpoint the use of fly ash for reinforcing aluminum alloys is extremely attractive due to its waste material character and expected low costs of production. In a study on the mechanical properties of hypoeutectic Aluminium silicon fly ash composites it is reported that an increase in the percentage of fly ash results in an increase in the hardness and tensile strength [7]. Charles *et al*. [8] studied the properties of aluminium alloy hybrid (Al-alloy/ Silicon carbide (SiC)/fly ash) composites. They reported that the wear and hardness were enhanced on increasing the volume fraction of SiC. They also reported that the tensile strength was high at 10 volume fraction of SiC and decreased as the volume fraction increased. Basavarajappa *et al*. [9] investigated the mechanical properties of aluminum alloy (Al2024) reinforced with SiC and graphite particles. Their results revealed that the mechanical properties such as ultimate tensile strength, yield strength, hardness and compressive strength of the composite increased predominantly with the increase in volume fraction of reinforcement. Sudarshan *et al*. [10] studied characterization of A356 Al-fly ash particle composites with fly ash particles of narrow range (53–106 μm) and wide size range (0.5–400 μm) and reported that addition of fly ash lead to increase in hardness, elastic modulus and 0.2 % proof stress. They also concluded that composites with narrow size range fly ash particle exhibit superior mechanical properties compared to composites with wide size range fly ash particles. Unlu, [11] studied the properties of Al based Al_2O_3 and SiC particle reinforced composite materials and found that mechanical properties like hardness of the composites significantly improved by the use of reinforcements.

The published literature on advanced materials, such as Aluminium cenosphere composites, is rather limited and is primarily concerned with applications of fly ash particles for synthesis of these materials. There is also a lack of information on the influence of light weight microsphere particles on the tensile behavior of the composites. Therefore, it was thought worthwhile to study: (1) the microstructural characteristics of aluminium composites reinforced with cenosphere particles, and (2) the relationships between the composite microstructure and tensile behaviour. The present work is dedicated to such an investigation.

2.0 EXPERIMENTAL PROCEDURE

The matrix material used here is Al 6061. This alloy is best suited for mass production of light weight castings. In this investigation cenospheres have been used as reinforcement. The cenospheres form in the temperature range between 920°C–1200°C.

2.1 Melting Procedure

The cleaned metal ingots are heated to a temperature of 800–850°C by placing in a graphite crucible. A filament winding type of induction furnace is used. A degassing agent in the form of Hexamethyelene di amine is added during the melting period. Magnesium is added in small quantities to improve the wet ability of the reinforcement particles with the base matrix. Cenosphere particles are then preheated and added to the molten metal and then continuously stirred by using a mechanical stirrer for a predetermined time. The cleaned metal moulds are then prepared by bolting together each part tightly so that no leakage of aluminium takes place. The melt with the reinforcement was then poured into the preheated metal moulds. The pouring temperature was maintained at 600°C. The melt was then allowed to solidify in the moulds. To compare the properties the base alloy was then cast in the same procedure.

2.2 Specimen Preparation and Testing

The test specimens were prepared by machining from the cylindrical bar castings. The specimens for microstructure studies were polished with a one micron diamond paste. The samples for the microscopic examination were etched with Kellers reagent as an etchant. The specimens were washed with distilled water followed by acetone and then dried thoroughly.

Hardness Test

Hardness tests were performed on the cast composites to know the effect of the reinforcement in the matrix material. The polished samples were tested using Vickers microhardness testing system. A load of 1 N for a period of 10 seconds was applied on the specimens. The hardness was determined by recording the diagonal lengths of the indentation produced. The test was carried out at five different locations and then the average value was taken as the hardness for the cast composites.

2.3 Tensile Test

The tensile tests were conducted on these samples according to ASTM E8-95 at room temperature, using a universal testing machine (INSTRON). The specimens used were of diameter 12.5 mm and Gauge length 62.5 mm, machined from the cast composites with the gauge length of the specimen parallel to the longitudinal axis of the castings.

3.0 RESULTS AND DISCUSSIONS

3.1 Microstructure

As the microstructure plays an important role in the overall performance of a composite and the physical properties depend on the micro-structure, reinforcement particle size, shape and distribution in the alloy [12], the cast samples were observed after subsequent polishing under an optical microscope. The micrographs shown in Figures 1–6 depict the microstructure of as cast Al6061 and fly ash reinforced Al6061 in varied percentages of 2,4,6,8 and 10 %.

Micrographs (Figures 1–6) clearly reveals minimal microporosities in the casting. No clustering of reinforcements was observed in the matrix, the reinforcements are seen well bonded in the matrix. It was also found that there was good bonding between matrix material and fly ash particles; however no gap is observed between the particle and matrix.

FIG. 1 AL 6061–0 % CENOSPHERE (200X)

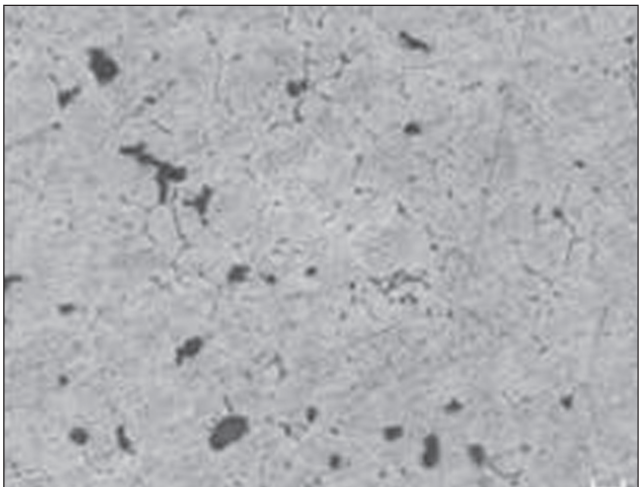

FIG. 2 AL 6061–2 % CENOSPHERE (200X)

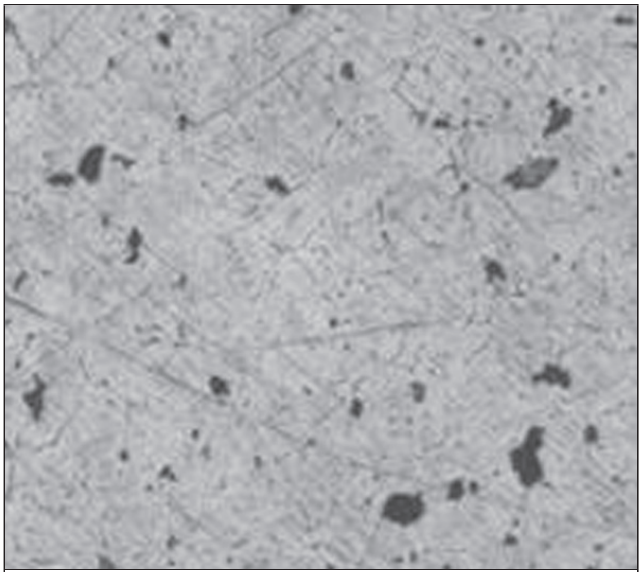

FIG. 3 AL 6061–4 % CENOSPHERE (200X)

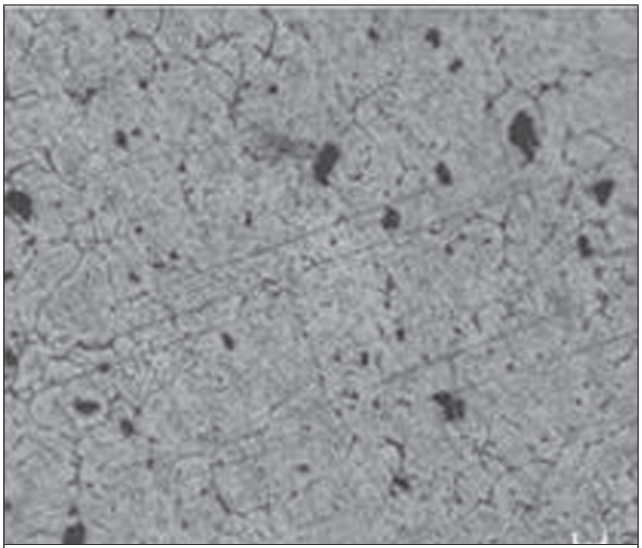

FIG. 5 AL 6061–8 % CENOSPHERE (200X)

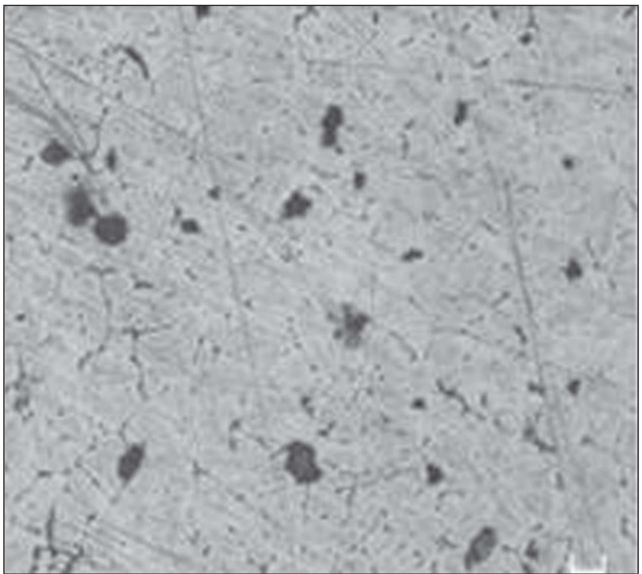

FIG. 4 AL 6061–6 % CENOSPHERE (200X)

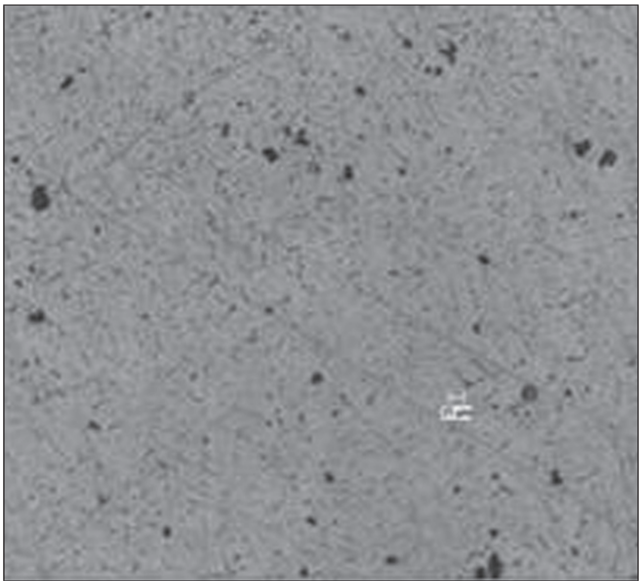

FIG. 6 AL 6061–10 % CENOSPHERE (200X)

3.2 Tensile Strength

Figure 7 shows the variation of ultimate tensile strength of the material with variation in the percentage of cenospheres. It is seen from the graph that there is a marked improvement in the tensile strength of the reinforced composite. Fly ash acts as barriers to the dislocations when taking up the load applied [9]. The hard fly ash particles obstruct the advancing dislocation front, thereby strengthening the matrix [13]. Another reason for the improvement in the ultimate tensile strength may be due to the matrix strengthening that might have occurred following a reduction in the composite grain size and the generation of a high dislocation density in the matrix as a result of difference in coefficients in thermal expansion between the matrix and the reinforcement [14]. A good bonding between the reinforcement and the soft aluminium matrix favors an enhancement of the ultimate tensile strength of the composite [15].

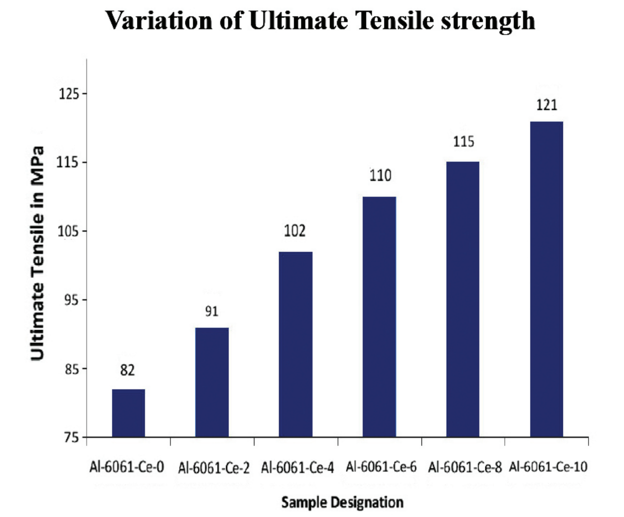

FIG. 7 VARIATION OF ULTIMATE TENSILE STRENGTH OF THE CAST COMPOSITES WITH INCREASING PERCENTAGE OF CENOSPHERES

3.3 Micro Hardness

Figure 8 shows the increase in the microhardness of the cast composites. It is seen that there is an increase in the hardness upon increasing content of the cenospheres. The dispersion of the fly ash particles enhances the hardness as particles harder than the matrix render their inherent property of the hardness to the soft matrix [16–17]. Similar reasons are also stated elsewhere for the increase in the hardness of the cast composites [7].

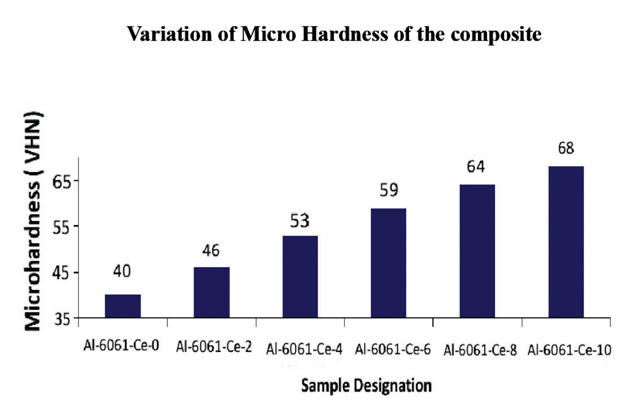

FIG. 8 VARIATION OF MICROHARDNESS WITH INCREASING CENOSPHERE PERCENTAGE

4.0 CONCLUSIONS

Based on the study conducted on the Aluminium cenosphere composites, the following conclusions can be made

(a) Forced vortex or stir casting method is chosen as an appropriate method to prepare the aluminium cenosphere composites.

(b) It is evident from the microstructure that there is a homogeneous distribution of the cenospheres in the matrix of Al 6061.

(c) There is a marked improvement in the ultimate tensile strength of the cast composites with the sample consisting of 10 % cenosphere showing the maximum increase in the tensile strength.

(d) The same is also attributed to the increase in the microhardness of the cast composite.

(e) The enhancement in the mechanical properties can be well attributed to the high dislocation density.

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