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Research Article

Development of Al-6Mg Flyash-Graphite Hybrid Metal Matrix Composites by stir casting and Evaluation of Mechanical Properties

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Abstract

The principal objective of the current investigation is to evaluate the effect of addition of reinforcement or dispersoid (Graphite and fly ash) in different weight percentage produced by stir-casting technique. In the field of engineering, metallurgists are looking for way to improve the mechanical properties of the materials. By doing so it is possible to improve the quality of the material which in turn gain the international market share. Therefore an investigation in the present research was made to fabricate and evaluate the Tensile and Compression strength, and hardness of Al matrix and Graphite and flyash particles as reinforcement in the matrix. Reinforcement being added ranges from 2 to 8 wt., % in step of 2%.

Keywords: *Graphite, Flyash, Stir Casting, Tensile Strength, Hardness*

1. Introduction

The hybrid metal matrix composites (MMCs) are a new range of advanced materials used in applications where conventional materials and alloys are not suitable for use. MMCs are a broad family of materials aimed at achieving an enhanced combination of properties. Structurally, MMCs consist of continuous or discontinuous fibers, whiskers or particles in an alloy matrix that solidifies in the restricting spheres between the reinforcing phase to form bulk of the matrix. By carefully controlling the relative amount and distribution of ingredients constituting a composite and by controlling the solidification conditions, MMCs can impart a tailored set of useful engineering properties that cannot be realized with conventional monolithic material.

There are more than eighty thousand materials represented in the market, and this figure is rapidly increasing. Advanced materials are being developed to an increasing extent (ASM Handbook). Among these materials one finds prominently used composite. The development of composites as a new engineering material has been one of the major innovations in the field of materials in the past couple of decades (Jatitz, 1990). The MMCs are a new range of advanced materials used in applications where conventional materials and alloys are not suitable for use. This out standing benefit of composite materials is that they can be tailored to produce various combinations of stiffness and strength (Berghezan, 1990; J.A.E. Bell, 1996).

Aluminum is one of the main elements used in the preparation of MMCs because of its comparatively low density, lightweight, good mechanical properties, good resistance to wear and corrosion. Also the melting point of Al is 590ºC which permits the fabrication of composites by methods involving low costs. Already the composites involving Al alloys used as the matrix are being considered for aerospace applications because of the best combination of strength and toughness they provide. Magnesium addition to aluminium reduces its casting fluidity at the same time as it reduces the surface tension of the aluminium sharply and increases mechanical properties (D.M. Miller, 1987; K. Shariq, 1999).

Fly ash is one of the residues generated in the combustion of coal. It is an industrial byproduct 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, SiO_2) (both amorphous 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 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 600m^2/kg. The specific gravity of fly

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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 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 MMCs. An increase in tensile strength and hardness of MMC with E-glass and flyash particulates was observed (E.I. Du Pont de Nemours, 1998).

The most conventional method of production of composites by casting route is vortex method, where the liquid aluminum containing 2-5% Mg is stirred with an impeller and ceramic particles are incorporated into vortex formed by stirring of the liquid metals and ensures uniform distribution of dispersion particulates and there by avoids the rejection of the particles from the melts (T.W.Clyne, 1993; A.Needleman, 1993).

2. Experimental Studies

The Composites were developed by stir casting method (vortex method). Al-Mg in the form of ingots were used for trials. The ingots were cut into pieces for accommodating them into graphite crucibles. The matrix material was super-heated to a temperature of 750-800^{0}c in a three phase electrical resistance furnace with temperature controlling device. For each melting 3-4 kg of alloy was used. The super-heated molten metal was degassed using a commercially available chlorine based tablet (hexa chloro ethane) and scum powder was used as slag removing agent. Graphite and fly ash particles were pre heated to around 400-500^{0}c were then added to the molten metal and stirred continuously by a mechanical stirrer at 760 rpm.. The Molten metal was heated to red hot condition and was continuously stirred using a graphite impeller to create a vortex. Vortex was created in the molten metal due to high speed of the stirrer, the speed was around 500rpm.The graphite rod was immersed to a depth of approximately one third the height of the molten metal from the bottom of the crucibleThe pre-heated reinforcement particles were introduced into melt. The wetting of the particles and the matrix was ensured by constant stirring which was carried out for more than 20 minutes to avoid agglomeration. The super heated melt was then poured into the pre heated metal mould to reduce the porosity and enhance the mechanical properties and composite rods of various dia were obtained (Ø25,50and 75mm).

Mechanical Tests

All mechanical tests were conducted in accordance with ASTM standards. Tensile tests were conducted at room temperature using universal testing machine (UTM) in accordance with ASTM E8M-16A. The tensile specimens Fig.1 of diameter 9 mm and gauge length 45 mm were machined from the cast composites with the gauge length of the specimen parallel to the longitudinal axis of the castings. The specimens were tested and average values of the UTS and Yield stresses were measured.

Fig.1 Tensile Specimens after Test

The compression tests were conducted on specimen Fig 2 of 13 mm diameter and 20 mm long machined from the cast composites. In these tests, the compressive loads were applied gradually and the compression strength was measured at the failure of the specimen. This test was conducted according to ASTM E9 standard on the UTM at room temperature.

Fig.2 Compression Specimens after Test

Hardness Test

The static indentation test (Brinell Hardness Tester) was used in the present study to examine the hardness of the specimens in which a ball indentor was forced into the specimens. The relationship of the indentor force to the indenting area provides value of hardness. Brinell hardness number (BHN) is expressed as the ratio of applied load to surface area of the spherical indentation mode. In this process of hardness determination when the metal is indented by a spherical tip. The tip first overcomes the resistance of the metal to elastic deformation and then a small amount of plastic deformation upon deeper indentation of the tip. It overcomes large deformation. For the BHN test, the surface of the specimen Fig. 3 on which the impression is to be made should smooth, clear, dry and free from oxides and scales to permit accurate measurement.

Fig.3 Hardness Specimens after Test

The hardness of the specimens were measured using a standard Brinell hardness testing machine as per ASTME-10.An indentor diameter 2.5 mm was used and a load of 31.25kg was applied over the specimens for a period of 30 seconds. Three readings were taken for each condition.

3. Results and Discussions

The Tensile tests were carried out on the composites developed by varying the wt% of Flyash and Graphite, to understand the variation of Ultimate Tensile Strength.

Fig.4, Fig.5 ,Fig.6 shows the variation in the Ultimate Tensile Strength (UTS) of various composites. The UTS of composites shows increasing trend with increasing % reinforcements.

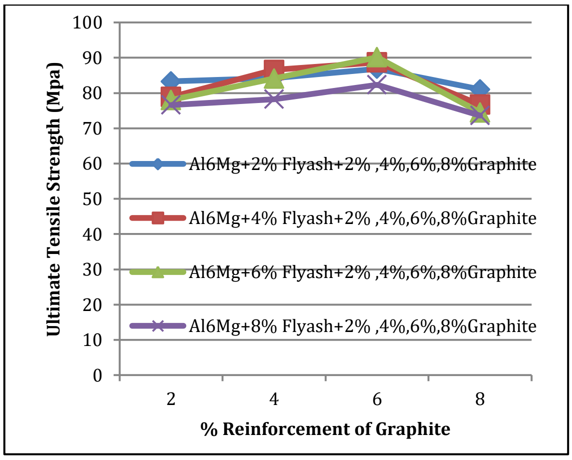

Fig. 5 (Ø25) Variation of UTS with % Reinforcements

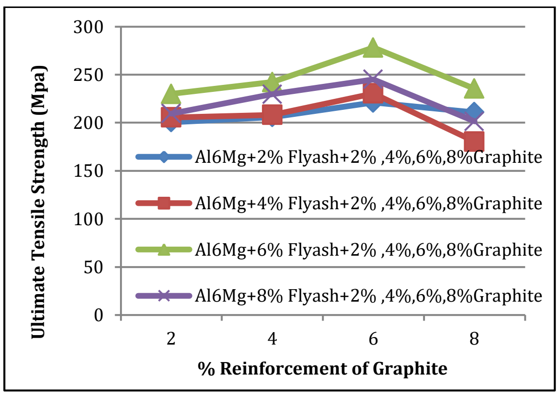

Fig. 6 (Ø50) Variation of UTS with % Reinforcements

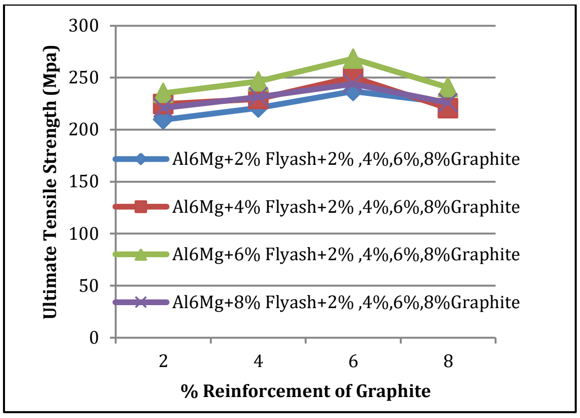

Fig. 7 (Ø75) Variation of UTS with % Reinforcements

There is increase in UTS upto Al6Mg+6% Flyash+ 2% ,4% , 6%,8% Graphite, further with increasing the reinforcement there is decrease in strength. This might be due to cluster formation. Similar trend has been observed for specimens of all diameters.

The Compression tests were carried out on the composites developed by varying the wt% of Flyash and Graphite, to understand the variation of Ultimate Tensile Strength. Fig 8, Fig 9 and Fig10 shows the effect of reinforcement particulate content on the compressive strength of the composites.

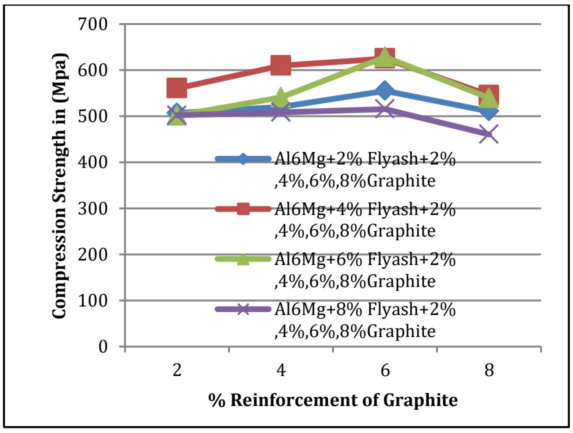

Fig. 8 (Ø25) Variation of UCS with % Reinforcements

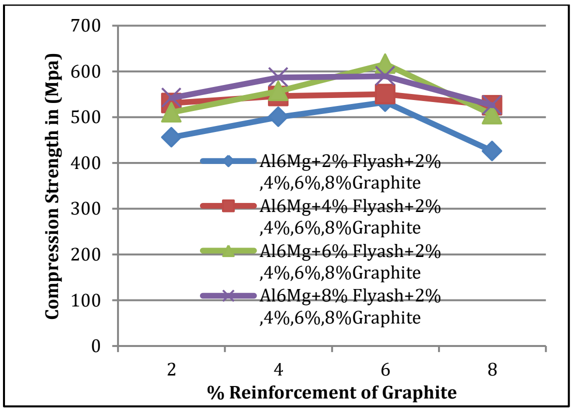

Fig. 9 (Ø50) Variation of UCS with % Reinforcements

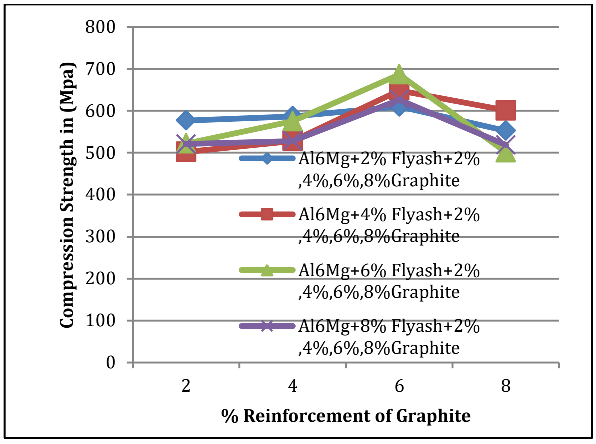

Fig. 10 (Ø75) Variation of UCS with % Reinforcements

The improvement of UCS is due to enhancement of dislocation density which leads to attributed to secondary hard phase and hence Al Mg+6% Flyash+ 2%, 4%, %,8% Graphite.

Composites became brittle, which were evident from the results obtained. Similar trend has been observed for specimens of all diameters.

The hardness variation of Al-6Mg composite is shown in Fig.11, Fig.12, and Fig 13. The hardness of the composite increases marginally with the increase of reinforcements addition.

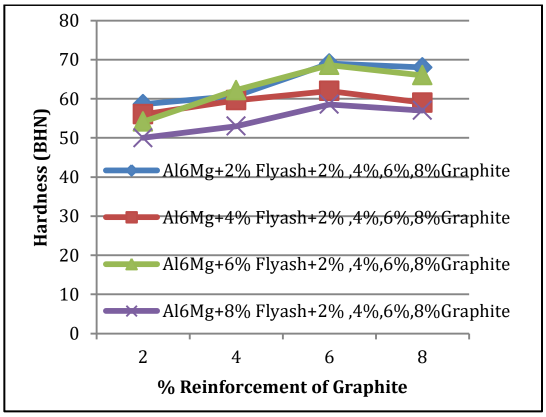

Fig. 10 (Ø25) Variation of Hardness with % Reinforcements

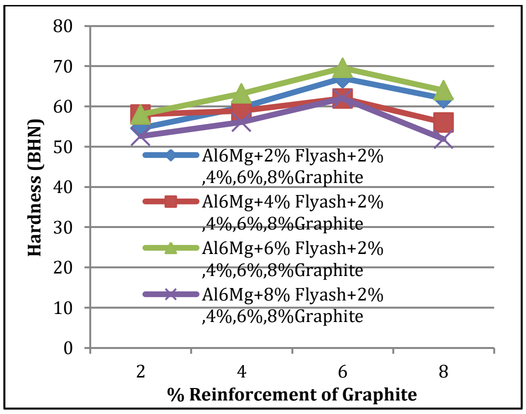

Fig. 11 (Ø50) Variation of Hardness with % Reinforcements

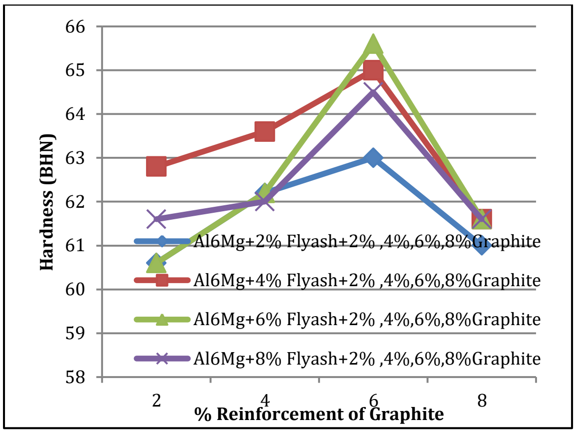

Fig. 12 (Ø75) Variation of Hardness with % Reinforcements

There is increase in hardness Owing to higher percentage & densification of the tough particles of Flyash and Graphite in composite.

Conclusions

- The composite castings with Al-6Mg as base material and Flyash-Graphite reinforcements with varying particles of 44μm mesh size (2 % to 8%) were successfully prepared by using stir casting technique.
- The Ultimate Tensile Strength of the Al6Mg+6% Flyash+ 6%, Graphite composite is 278.2 MPa for 50 mm dia specimen, compared to other diameter specimens. This might me due to uniform distribution of flyash and graphite in the matrix.
- The Compression Al6Mg+6% Flyash+ 6%, Graphite composite is 686 MPa for 75 mm dia specimen, compared to other diameter specimens. This might me due to hard particles of flyash and graphite in the matrix.
- The Hardness of Al6Mg+6% Flyash+ 6%, Graphite composite is 69.6 for 50 mm dia specimen, compared to other diameter specimens. This might me due to uniform distribution of hard particles of flyash and graphite in the matrix.

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