EVALUATION OF MECHANICAL PROPERTIES OF AL6061, FLYASH AND E-GLASS FIBER REINFORCED HYBRID METAL MATRIX COMPOSITES

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ABSTRACT

Flyash-eglass-Al6061 alloy composites having 2 wt%, 4 wt%, 6wt% and 8wt% of flyash and 2 wt% and 6wt % of e-glass fiber were fabricated by liquid metallurgy (stir cast) method. The casted composite specimens were machined as per test standards. The specimens were tested to know the common casting defects using ultra-sonic flaw detector testing system. Some of the mechanical properties have been evaluated and compared with Al6061 alloy. Significant improvement in tensile properties, compressive strength and hardness are noticeable as the wt % of the flyash increases. The microstructures of the composites were studied to know the dispersion of the flyash and e-glass fiber in matrix. It has been observed that addition of flyash significantly improves ultimate tensile strength along with compressive strength and hardness properties as compared with that of unreinforced matrix.

Keywords: flyash, e-glass fiber, Al6061 alloy composite, mechanical properties, stirs casting.

INTRODUCTION

There have been tremendous strides in engineering materials since the Second World War. Metallurgists from the aerospace and nuclear industries have developed a large range of super alloy and heat resistance materials mnemonics like ceramics and composite materials. With the vast and rapid progress in science and technology, modern industry has introduced a new generation of composite materials having low density and very light weight with high strength, hardness and stiffness to meet the current needs of modern technology and the challenges against liberalization and global competitiveness in market [1]. Particle-reinforced aluminum alloys have the potential to be used in a wide range of such engineering applications due to their higher stiffness and strength when compared with conventional aluminum alloys. For these materials, silicon carbide (SiC), a commercially pure material, has become the main type of reinforcement used [2]. And most of the research work carried out on aluminium based composite materials involves silicon carbide as its reinforcing material. Therefore it is essential to look for the possibilities of fabricating aluminium based composite materials using waste or recycling materials like fly ash.

Most of energy needs in the century is relied on the fossil fuels. Combustion of coal energy produces waste by product, i.e., fly ash in abundance. The disposal of this fly ash is a major challenging task [3].

In this work, an attempt has been made to fabricate a hybrid composite material from commercial pure material and waste product. Short e-glass fibers are used as commercially pure material and fly ash as waste product. Aluminium 6061 is used as matrix material for the fabrication of Al-e-glass-fly ash hybrid composite material. However in order for this idea to become a technological and commercial reality, the effect of a number of processing parameters on the composites properties and performance must be fully understood first [3].

EXPERIMENTAL PROCEDURES

The matrix material used for the MMCs in this study is Al6061. This alloy is best suited for mass production of lightweight metal castings. Al6061 alloy has numerous benefits like formability, weldability, corrosion resistance and low cost. Table-1 shows the chemical composition of Al6061 alloy and Table-2 shows the chemical composition of the E-glass fiber. Fine fly ash of 60 grade and E- glass fiber of 2-3 mm length were reinforced in the matrix material. Liquid metallurgy technique was used to fabricate the composite materials in which the reinforcing materials were introduced into the molten metal pool through a vortex created in the melt by the use of alumina coated stainless steel stirrer. The coating of alumina to the blades of the stirrer is essential to prevent the migration of ferrous ions from the stirrer into the molten metal. The stirrer was rotated at 550 rpm and the depth of immersion of the stirrer was maintained about two-thirds the depth of the molten metal. The pre heated reinforcing materials were added one after the other into the vortex of the liquid melts which was degassed using pure nitrogen for about 3-4 minute. The resulting mixture was tilt poured into the preheated permanent metallic molds.

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Table-1. Chemical composition of Al6061 by weight percentage.

Mg (Magnesium)	0.920 %
Si (Silicon)	0.750 %
Fe (Ferrous)	0.280 %
Cu (Copper)	0.220 %
Ti (Titanium)	0.100 %
Cr (Chromium)	0.070 %
Zn (Zinc)	0.060 %
Mn (Manganese)	0.040 %
Be (Beryllium)	0.003 %
V (Vanadium)	0.010 %
Al (Aluminium)	Balance

Table-2. Chemical composition of E-Glass fiber by weight percentage.

SiO_2	Al_2O_3	CaO	MgO	B_2O_3
54.3 %	15.2 %	17.2 %	0.6 %	8.0 %

SPECIMEN PREPARATION AND TESTING

The test specimens were prepared by machining from the cylindrical bar castings. Each specimen having 8 mm in diameter X 60 mm gauge length in size for tensile testing and 20 mm diameter X 20 mm length for compression testing were prepared. The specimen surfaces were polished with 1 µm diamond paste. The samples for microscopic examination were etched with Keller's reagents as etchant. The specimens were washed with distilled water followed by acetone and dried thoroughly.

Tensile test

Test specimens were prepared according to ASTM E8-82 standards, each specimen having 8mm in diameter and 60mm gauge length, as shown if Figure-1. The specimen was loaded in Hounsfield Universal Testing Machine until the failure of the specimen occurs. Tests were conducted on composites of different combinations of reinforcing materials and ultimate tensile strength and ductility were measured.

For conducting a standard tensile test, a specimen that has been measured for its cross-sectional area and gauge length is placed in the testing machine and the extensonometer is attached. Simultaneous readings of load and elongation are taken at uniform intervals of load. Uniaxial tensile test is conducted on the fabricated specimen to obtain information regarding the behavior of a given material under gradually increasing stress strain conditions. Figure-2 shows some tensile test specimen after testing.

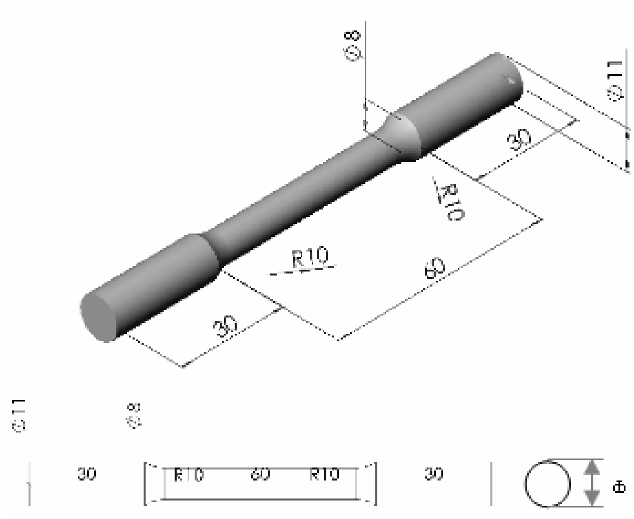

Figure-1. Tensile test specimen.

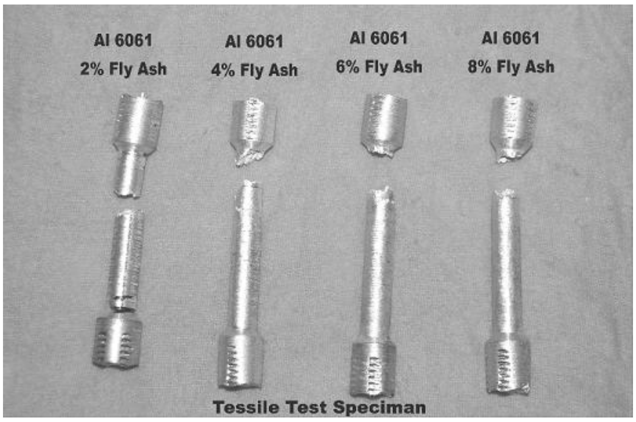

Figure-2. Composite specimen after tensile test.

Compression test

Compression tests are run in much the same manner as the tension test on the specimen having 20mm diameter and 20mm length. Testing is carried out on Universal Testing Machine. The load interval given was 2 tons. For each load interval, respective change in length is measured and same is recorded until breaking takes place. A compressive stress - strain curve is plotted. From this curve, the behavior of the test specimen under compression can be predicted. From the graph, compressive properties of the test specimen, such as Compressive strength, are calculated.

Hardness test

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

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RESULTS AND DISCUSSIONS

Microstructure analysis

Figure-3 shows the microstructure of as cast Al6061 alloy in the received samples. Precipitations were evident both in the grains and along grains. Figure-4 shows typical microstructure of the Al 6061 and Hybrid Composites containing 6 % Fly ash and 2 % e-glass fiber. The grain size of the matrix alloy is somewhat larger than that of the composites. Micrograph clearly reveals minimal micro porosities in the casting. No clustering of reinforcements was observed in the matrix, and the dispersion of fly ash particles and e-glass fiber was seen to be almost uniform. No gap is observed between the particle and matrix and between the fiber and the matrix, and reinforcing materials are seen well bonded with the matrix.

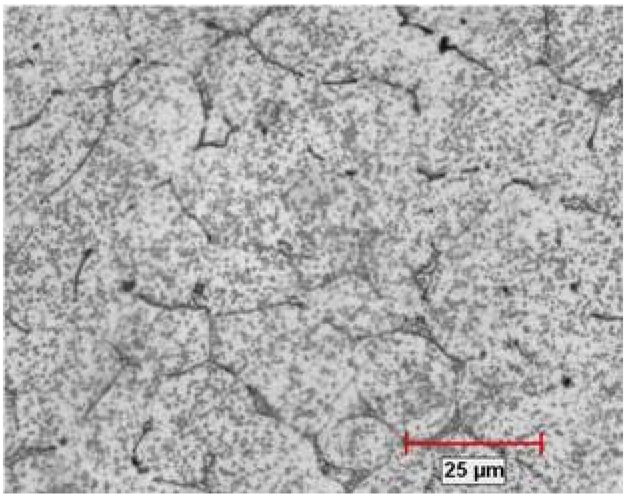

Figure-3. Microstructure of as cast Al6061 alloy.

Tensile strength

Figure-5 shows the effect of fly content and e-glass fiber on ultimate tensile strength of composite material. Similarly Figure-6 shows the variation of yield strength with increase in the fly ash and e-glass fiber content in the Al6061 composite material. In both the cases the addition of fly ash to Al6061 matrix is increasing the tensile strength of the composite material.

From the graph it is also evident that the yielding point of the composite samples also increased substantially with increase in reinforcements.

This may be because of as more glass fibers were added, decrease in inter-fiber distance between hard glass fibers caused an increase in dislocation pile-up. By increasing the wt% of fly in the Al6061 alloy matrix, dispersion of fly ash particles in a soft ductile Al6061 alloy matrix results in improvement in strength [4]. And improvement in UTS may be due to the matrix strengthening that might have occurred following a reduction in composite grain size and the generation of a high dislocation density in the matrix as a result

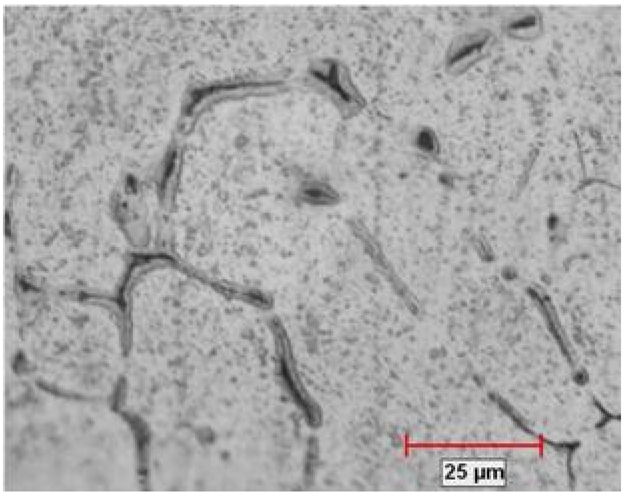

Figure-4. Microstructure of 6 wt% fly ash, 2 wt% e-glass fiber, Al6061 composite specimen.

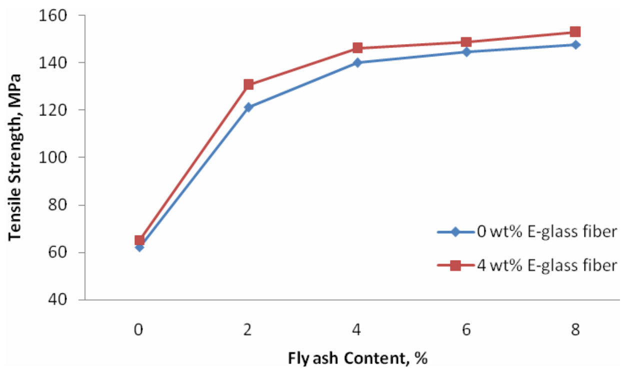

Figure-5. Effect of variation of fly ash and e-glass fiber on ultimate tensile strength of composite material.

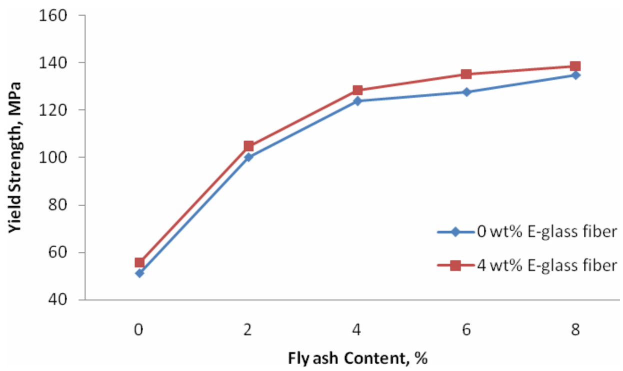

Figure-6. Effect of variation of fly ash and e-glass fiber on yield strength of composite material.

of difference in coefficient of thermal expansion between matrix and reinforcements [5-9]. Weldability is one of the dominating factors to ensure good bonding between the matrix and reinforcement [9]. A good bonding between reinforcement and soft aluminium matrix favors an enhancement of the ultimate tensile strength of the composite [10].

Compressive strength

Figure-7 shows the results obtained from uniaxial compression, as a function of fly ash content of the matrix. Increase in the content of fly ash and e-glass fiber increases the compressive strength of the composites.

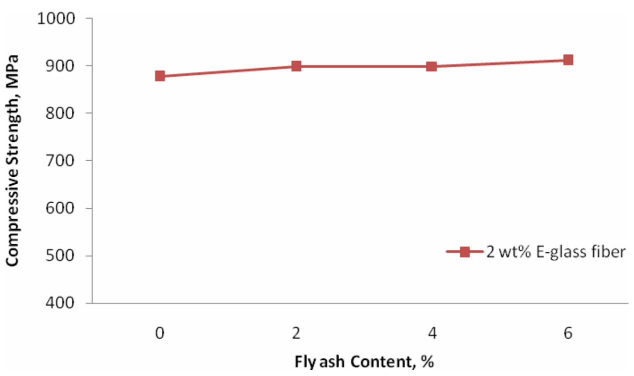

Figure-7. Effect of variation of fly on compressive strength of composite material.

The increase in compressive strength is due to the increase in the density of the composite material. It is shown that addition of ceramic reinforcement to a soft matrix increases its density and there by its compressive strength [11]. Similar results were demonstrated in various studies made on the compressive strength of composite materials [12-16].

Micro hardness results

Hardness tests were performed on as cast and composites to know the effect of fly ash in matrix material. The polished specimens were tested using Vickers micro hardness testing system. A load of 1N for a period of 10 seconds was applied on specimens. The hardness was determined by recording the diagonal lengths of indentation produced. The test was carried out at three different locations and the average value was taken as the hardness of the as cast and composite specimens. Figure-8 shows the results of micro hardness test on as cast Al6061 alloy and composite containing different wt% of fly ash in it.

From the Figure it is evident that the hardness of the composite material is much higher then that of its parent metal. It is also shown that the hardness of the composite material increases with wt% of fly ash content. This may be because of addition of fly ash makes the ductile Al6061 alloy into more brittle in nature with increase in the fly ash content. And also the dispersion of fly ash particles enhances the hardness, as particles are harder than Al6061 alloy, and render their inherent property of hardness to soft matrix [16-17].

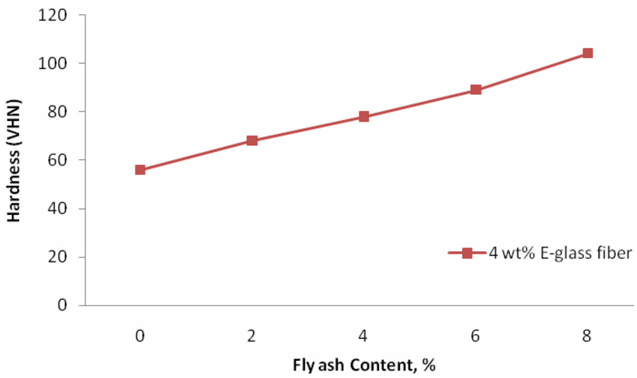

Figure-8. Effect of variation of fly on hardness value of composite material.

CONCLUSIONS

Based on the study conducted on the fly ash, e-glass containing Al6061 composite material, the following conclusions can be made:

a) Using stir casting method, fly ash and e-glass fiber can be successfully introduced in the Al6061 alloy matrix to fabricate hybrid composite material;
b) From the microstructure analysis it is evident that the composites fabricated have fairly even distribution of reinforcements in the composite material;
c) The tensile of composite material compared to the as cast Al6061 alloy, increased significantly by 60-70%;
d) The improvement in compressive strength is also observed but it was marginal. Further improvement in compressive behavior of composite can be achieved by incorporating fabrication method other then stir casting method; and
e) The hardness of the composite material also increased with increase in wt% of fly ash content in the composite. This is due to the strengthening of Al6061 alloy matrix by the fly ash particles.

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