

EVALUATION OF MECHANICAL PROPERTIES OF Al 7075-FLY ASH COMPOSITE MATERIAL

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Abstract: Composites are most successful materials used for recent works in the industry. Metal composites possess significantly improved properties including high tensile strength, toughness, hardness, low density and good wear resistance compared to alloys or any other metal. There has been an increasing interest in composites containing low density and low cost reinforcements. Among various reinforced materials used, fly ash is one of the most inexpensive and low density reinforcement available in large quantities as waste product during combustion of coal in thermal power plants as well as in the brick factory and rice mill. Hence, composites with fly ash with Al 7075 as reinforcement are likely to overcome the cost barrier as well as the different physical and mechanical properties for widely used in the automotive and space craft applications.

Keywords: Aluminium Matrix Composites, Fly Ash, Stir Casting, Grain Size, X-Ray Diffraction

I. INTRODUCTION

Conventional monolithic materials have limitations in achieving good combination of strength, stiffness, toughness and density. To overcome these shortcomings and to meet the ever increasing demand of modern day technology, composites are most promising materials of recent interest. Metal composites possess significantly improved properties including high specific strength, specific modulus, damping capacity and good wear resistance compared to unreinforced alloys. There has been an increasing interest in composites containing low density and low cost reinforcements. Among various discontinuous dispersoids used, fly ash is one of the most inexpensive and low density reinforcement available in large quantities as solid waste by-product during combustion of coal in thermal power plants. Hence, composites with fly ash as reinforcement are likely to overcome the cost barrier for wide spread applications in automotive and small engine applications. It is therefore expected that the incorporation of fly ash particles in aluminium alloy will promote yet another use of this low-cost waste by-product and, at the same time, has the potential for conserving energy intensive aluminium and thereby, reducing the cost of aluminium products.

Now the days the particulate reinforced aluminium composites are gaining importance because of their low cost with advantages like isotropic properties and the possibility of secondary processing facilitating fabrication of secondary components. Cast aluminium matrix particle reinforced composites have higher specific strength, specific modulus and good wear resistance as compared to unreinforced alloys.

In the present work, fly-ash which mainly consists of refractory oxides like silica, alumina, and iron oxides is used as reinforcing phase. Composite was produced with 10gm to 40gm fly-ash as reinforcing phase. Commercially pure aluminium was also melted and casted. Then particle size and chemical composition analysis for fly-ash was done. Mechanical, physical and grain properties of the composite were evaluated and compared with the commercially pure aluminium. Mechanical properties of composites are affected by the size, shape and volume fraction of the reinforcement, composite material and reaction at the interface. These aspects have been discussed by many researchers. P.K. Rohatgi [1] reports that with the increase in volume percentages of fly ash, hardness value increases in Al-fly ash (precipitator type) composites. He also reports that the tensile elastic modulus of the ash alloy increases with increase in volume percent (3–10) of fly ash. J. Babu Rao [2] studies that Metal matrix composites (MMCs) possess significantly improved properties compared to unreinforced alloys. There has been an increasing interest in composites containing low density and low cost reinforcements. Among various dispersoids used, fly ash is one of the most inexpensive and low density reinforcement available in large quantities as solid waste by-product. In the present investigation, pure aluminium – 5 to 15% (by weight) fly ash composites were made by stir casting route. P. Shanmughasundaram [3] studied the Development of lightweight materials has provided the automotive industry with numerous possibilities for vehicle weight reduction. Progress in this area depends on the development of materials, processing techniques, surface and heat treatments Aluminium matrix ceramic reinforcement composites have attracted increasing attention due to their combined properties such as high specific strength, high stiffness, low thermal expansion coefficient and superior dimensional stability at elevated temperatures as compared to the monolithic materials.

II. EXPERIMENTAL WORK

2.1 Heat Treatment of Fly Ash

Before directly using the fly ash in the composite heat treatment is done on it to remove impurities and water content. For the surface treatment of ash it is heated in the furnace at a temp. of 600°C. During this temp. range a ethanol solution is added at a temp. of 50°C and stir for some time. After it we also added cover11 to improve its surface characteristics.



Figure 1: Fly Ash

2.2 Fabrication of Al7075-Fly Ash Composites

As we done the heat treatment of fly ash that taken from the thermal plant to reduce its moisture in the induction furnace. After it we have to melt the Al 7075 in the furnace having a capacity of 1000°C and then added preheated fly ash into it. For increasing wettability, we also added the Mg that means it decreases the surface tension of the fly ash. For better mixing of all materials, a stirrer arrangement is adjusted which stirs the molted composite material. Also an Hexachloro-ethane tablets are using here to remove the slag from the molten MMC. After all of these, this molten material will be poured into the sand mould and fabricate the required shape of slab and rods.



Figure 2: Stir Casting Arrangement

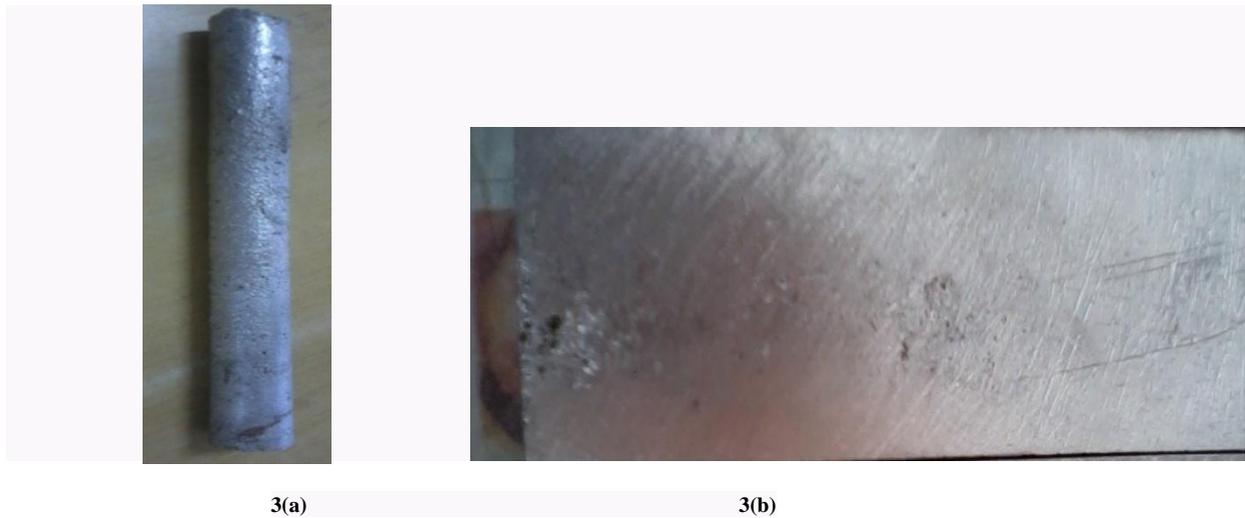


Figure 3: (a) Cast Rod and (b) Slab of Aluminium Matrix Composite

Table 1: Composition Used For Metal Matrix Composite

No. of Samples	Aluminium(7075) (gm)	Magnesium (gm)	Fly Ash (gm)	Total Weight (gm)
S1	500	10	40	550
S2	500	20	30	550
S3	500	30	20	550
S4	500	40	10	550

2.3 Characterization of Al 7075- Fly Ash Composites

2.3.1 Toughness Test

The toughness is the energy requires breaking the material. The energy is calculated in joules. The energy consumed is calculated by the difference between total energy supplied to the energy available at the end. The measure of toughness can be found with the help of Charpy and Izod impact tests. The standard specimen size for Charpy impact testing is 10mm×10mm×55mm. and for Izod impact testing 10mm×10mm×75mm.



Figure 4: 4(a) Izod And 4(b) Charpy Test Specimen Before and After Testing

2.3.2 Hardness test

Hardness is the measure of how resistant solid matter is to various kinds of permanent shape change when a force is applied. Macroscopic hardness is generally characterized by strong intermolecular bonds. There are three types of tests used with accuracy by the metals industry; they are the Brinell hardness test, the Rockwell hardness test, and the Vickers hardness test. But in our present work we considered only Rockwell hardness test. The Rockwell scale is a hardness scale based on the indentation hardness of a material. The Rockwell test determines the hardness by measuring the depth of penetration of an indenter under a large load compared to the penetration made by a preload.



Figure 5: Hardness Test Specimen 5(a) Before and 5(b) After Testing

2.3.3 Tensile Test

Tensile testing, also known as tension testing, is a fundamental materials science test in which a sample is subjected to uni-axial tension until failure. The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under other types of forces. Properties that are directly measured via a tensile test are ultimate tensile strength, maximum elongation & reduction in area.



Figure 6: Tensile Test Specimen 6(a) Before and 6(b) After Testing

2.3.4 Density

Moreover density also plays a vital role in the composite material study. As these materials having a scope in the automotive industry as well as in the space crafts, they must be of light weight. So the density should be reduced by adding some reinforced material like a fly ash of very low density. Density can be calculated by dividing the mass of specimen by the volume displaced by that specimen in the water beaker.

2.3.5 Grain Size

Grain size will be calculated by testing the specimen under optical microscope or by using the data derived from XRD. Grain size is normally quantified by a numbering system. Coarse 1-5 and fine 5-8 . The number is derived from the Sherrer formula. Which is given by:-

$$B = \frac{0.9 \lambda}{t \cos \theta}$$

Where t is the grain size of the atom, B is FWHM value, θ is bragg angle & lemda is the wavelength of x-ray. Grain size has an important effect on physical properties. For service at ordinary temperatures it is generally considered that fine grained give a better combination of strength and toughness, whereas coarse grained steels have better machinability. The value of λ for copper that is used in the XRD machine is 1.54 Å.

2.3.6 X-Ray Diffraction Testing

X-ray scattering techniques are a family of non-destructive analytical techniques which reveal information about the crystal structure, chemical composition, and physical properties of materials and thin films. These techniques are based on observing the scattered intensity of an X-ray beam hitting a sample as a function of incident and scattered angle, polarization, and wavelength or energy. X-ray crystallography is a method of determining the arrangement of atoms within a crystal, in which a beam of X-rays strikes a crystal and causes the beam of light to spread into many specific directions. From the angles and intensities of these diffracted beams, a crystallographer can produce a three-dimensional picture of the density of electrons within the crystal.

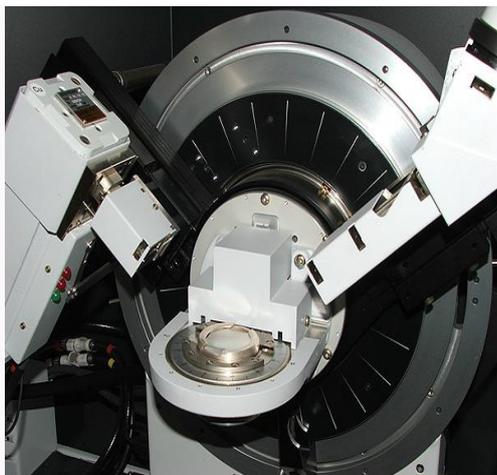


Figure 7: XRD Testing Machine



Figure 8: XRD Specimen

III. RESULTS & DISCUSSIONS

Table 2: Experimental Data for Al 7075-Fly Ash Composites

SAMPLE	IZOD TEST (MPa)	CHARPY TEST (MPa)	TENSILE TEST (MPa)	HARDNESS (HRB)	GRAIN SIZE (µm)	DENSITY (g/cc)
S1	3.20	3.63	125	70	0.22	2.25
S2	5.33	5.20	140	77	0.18	2.30
S3	4.26	4.66	135	75	0.15	2.43
S4	4.00	3.86	133	68	0.12	2.59
Al- 7075						2.81

3.1 Mechanical Properties of Al 7075- Fly Ash Composites

Fig.9 shows the effect of fly ash on the strength of Al 7075. As we earlier studied about the tests we made on composites, 9(a) & 9(b) shows for izod and charpy. From both of graphs, we can conclude that as the ash content increases strength of the composites also increases but up to some level and after this it reduces. The level up to it increases is the 30gm of ash content for sample2. The data for all the experiments are mentioned in the above table 2.

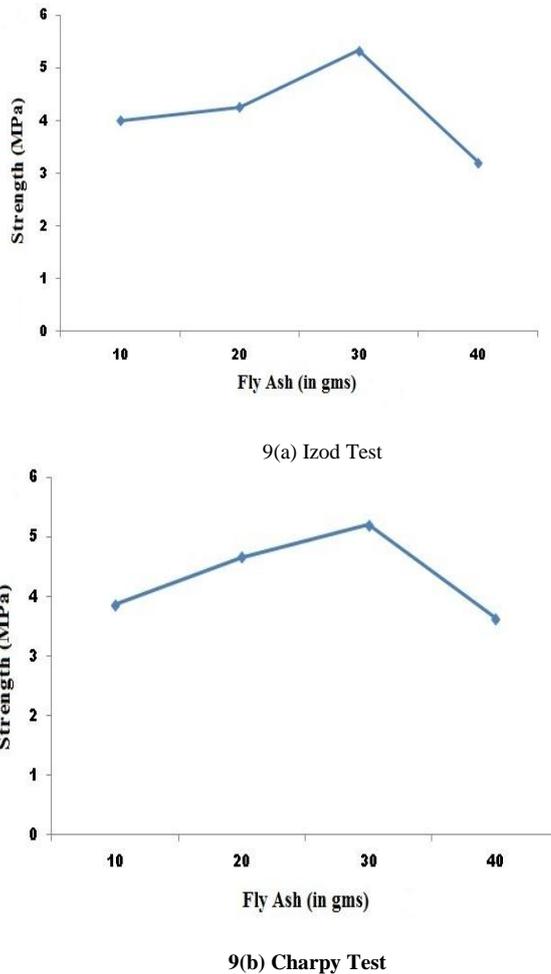
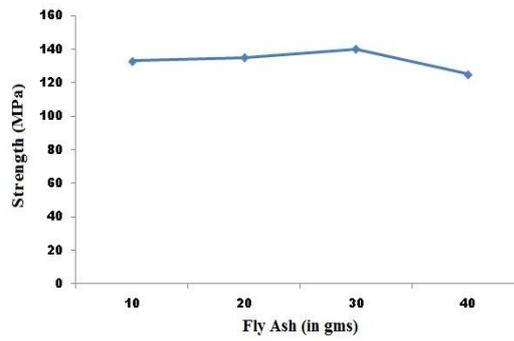
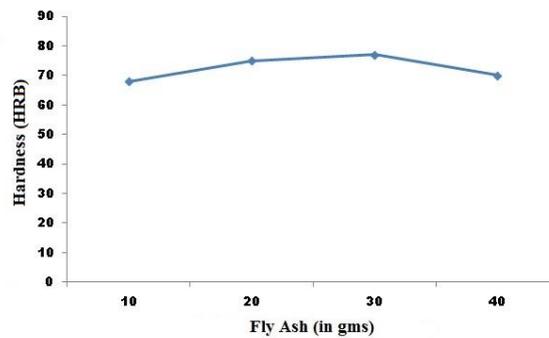


Figure 9: Effect of Fly Ash on the Strength of Al7075 by 9(a) Izod Test and 9(b) Charpy Test

Fig. 10 shows the effect of fly ash on the tensile strength and hardness of Al 7075. Here 10(a) & 10(b) shows for tensile test and rockwell hardness test. From both of graphs, we can conclude that as the ash content increases strength and hardness of the composites also increases but up to some level and after this it reduces as like in the case of izod and charpy tests. The level up to it increases is the 30gm of ash content for sample2. However the tensile strength and hardness begins to drop when the fly ash content exceeds 30gm due to decrease in solid solution strengthening. As we added ash in the aluminium both having different atomic size which increases the stress required to move the dislocation through the crystal but this phenomena occurs up to some level.



10(a) Tensile Test

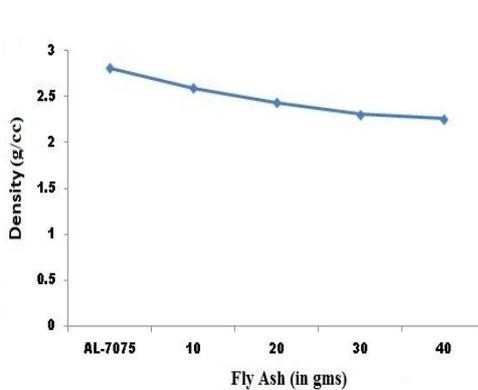


10(b) Hardness Test

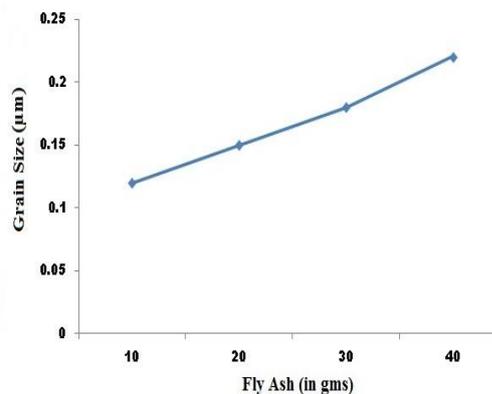
Figure 10: Effect of Fly Ash on the 10(a) Tensile Strength and 10(b) Hardness of Al7075

3.2 Physical Properties of Al 7075- Fly Ash Composites

As earlier studied that we required a light weight composite material which will be used in the automobile and aerospace industries, this Al 7075- Fly Ash composites are best for this applications due to their low density. Fig.11 shows the effect of fly ash on the density and grain size of the composites we fabricated. Fig. 11(a) shows the effect of fly ash on the density. As the ash content increases the density of the composites reduces which is good for us as they used in the light weight applications. Fig. 11(b) shows the effect of fly ash on the grain size of composite. As we increases the ash content the grain size of composites also increases due to the coarse nature of ash.



11(a) Density



11(b) Grain Size

Figure 11: Effect of Fly Ash on the 11(a) Density and 11(b) Grain Size of Al7075

3.3 Structural Study of Al 7075- Fly Ash By Using X-Ray Diffraction

With the help of XRD, we examined the different crystal structure presented inside of Aluminium Matrix Composites as well as the grain size of the various atoms. Fig. 12 shows the graphical view by XRD for all composites having different ash ratio. Fig.12(a) shows the presence of different crystal structures at the diff. positions of Bragg's angle(2θ) at diff. counts. This graph is plotted by using the software High Score+. At the various position of Bragg's Angle diff. elements are presented as like of Al at (38.5254, 65.1470 & 99.105) and Aluminium Zinc at (44.7676, 78.2741 & 82.4856) as shown in Fig.12(b). Almost 83% of Al and 17% of AlZn presented in the composite by its weight fraction% which is calculated with the help of jcpds cards.

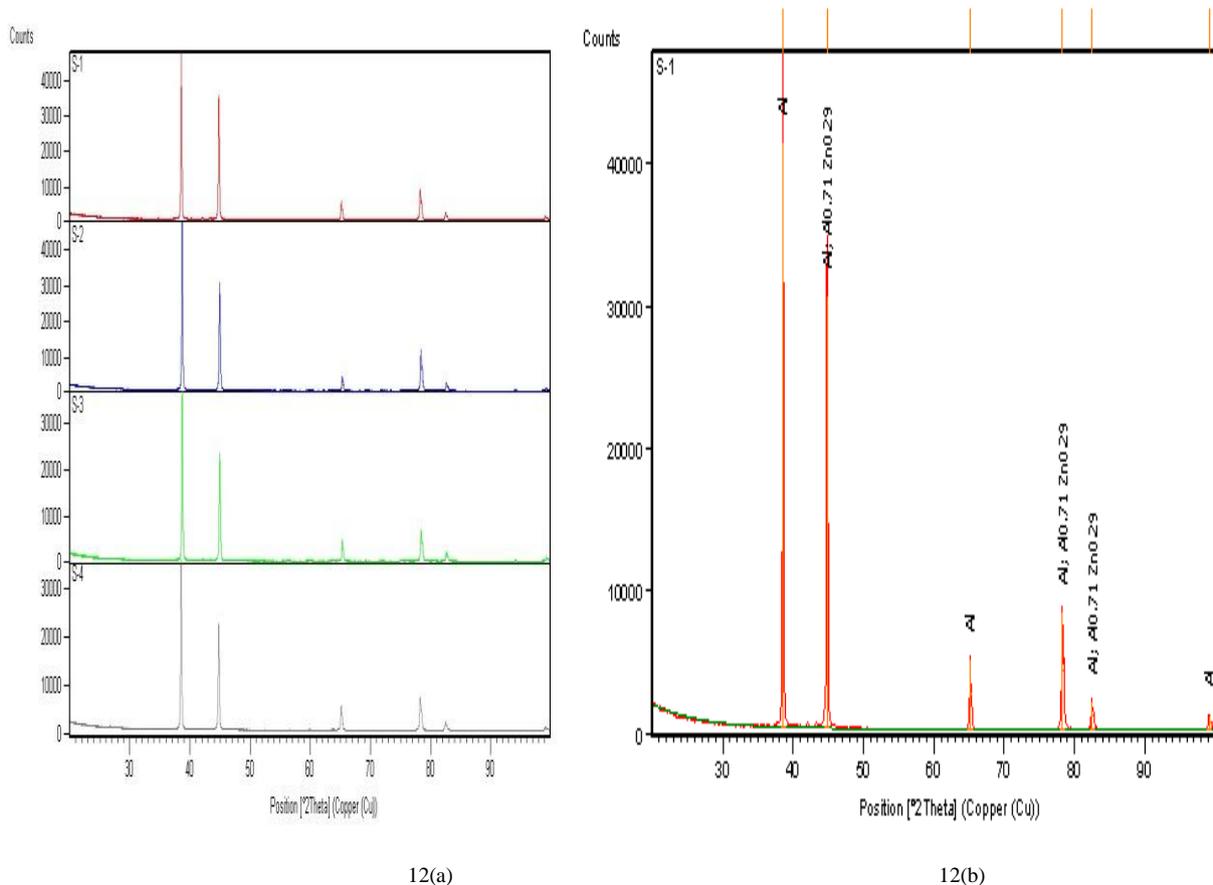


Figure 12: XRD Graphs By Using High Score+ shows 12(a)Amount of Ash in Composite and 12(b)Crystal Structure by indexing Diffraction Pattern

IV. CONCLUSIONS

Here we successfully fabricated the Al 7075-Fly Ash Composites by using Stir Casting arrangement with proper distribution of ash particles all over the specimen. Also we added the Mg to improve the wettability of an ash particles by reducing its surface tension. We have drawn various conclusions from the various calculations based on the diff. experimental testes:

- Toughness of the composites was determined by using Izod and Charpy tests. As we increase the amount of ash the toughness value gradually increased up to some level i.e Sample2 but after this it diminishes.
- Hardness and tensile strength of the composites also showed the same results as like of toughness. As we increased the amount of ash up to Sample2 it increases and after that goes down.
- The density of the composites decreased with increasing ash content. Hence these light weight composites can be used where weight of an object matters as like in the aero and space industries.

From the above results we find the Sample2 having an good toughness, hardness, tensile strength and also having the low density comparatively alloys without reinforcement. So that these composites could be used in those sectors where light weight and good mechanical properties are required as like in automobile and space industries.

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BIOGRAPHY



Myself Deepak Singla graduated in 2010 with 75% (hon's) and pursuing my master degree in manufacturing science with 72% from Kukrukshetra university. Presently I am working my thesis under the guidance of Dr. S.R. Mediratta(DG). My research interest is in the material science and mechanical vibration.