Comparative Study on hardness of As-cast and heat treated Al based hybrid composites

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Abstract—**Traditional materials do not always provide the necessary properties under all service conditions. Metal Matrix Composites (MMCs) are advanced materials resulting from combination of two or more materials in which tailored properties are realized. They have received considerable attention in the recent years due to their high strength, stiffness and low density.**
In the present investigation, an Al-Zn based alloy was used as the matrix and fly ash, E-glass were used as the reinforcements. Different composites were produced, using stir casting technique by varying E-glass with constant fly ash and vice versa (1 to 3 %). The microstructures of the composites were studied to know the dispersion of fly ash and E-glass fibers in the matrix.
Test specimens were prepared as per the ASTM standard size by turning and facing operations to conduct hardness test. The composites were subjected to solution heat treatment and tested.
Significant improvement in hardness was observed with the addition of reinforcements. Further, it was observed that the properties of heat treated composites were enhanced when compared to as cast composites.

***Key words*: MMC, Al-Zn alloy, Fly ash, E-glass, Stir casting, Heat treatment.**

1. INTRODUCTION

Materials are the essential part of engineering industry. An engineer needs materials to give shape to his/her concept and design [1]. In general, materials of high strength will have relatively high density. Materials for aerospace, automobile, transportation and structural application should have low density but yet strong and hard. Conventional materials will not posses this unusual combination of prosperities. The mechanical and tribological prosperities of various materials can be improved by forming new class of materials known as composites [2,3]. A composite material is defined as a structural material formed artificially by combining two or more materials having dissimilar characteristics [4]. A composite is designed to display a combination of the best characteristics of each of the component materials [2]. Metal Matrix Composites (MMCs) consists of either pure metal or an alloy as the matrix material, while the reinforcement generally a ceramic material [5].

Aluminum is the most popular matrix for the metal matrix composites. The Al alloys are quite attractive due to their low density, capability to be strengthened by precipitation, good corrosion resistance, and high thermal and electrical conductivity. Aluminum Matrix Composites (AMCs) are the class of light weight high performance materials [6-9]. The reinforcements in AMCs could be in the form of continuous/discontinuous fibers, whisker or particulates [10]. In the present investigation fly ash, E-Glass are reinforced with Al 7075 alloy matrix which is a high strength alloy mainly used in aerospace applications. Fly ash is the residue resulting from the combustion of coal in thermal power plants and is one of the inexpensive low dense reinforcement with excellent engineering properties [11]. E-Glass is used as reinforcing phase which has excellent fiber forming capability with all-round good properties.

2. EXPERIMENTAL WORK

The matrix material for this experimental investigation is commercially available aluminum AA7075 in the form of ingots. The reinforcements are fly ash particulates in the range of 0.1 to 100 µm and E-Glass short fibers of length 2 to 3 mm .The hybrid composite is formed by stir casting method. An electric resistance furnace was used for melting the alloy. The ingots of the alloy were cut into small pieces and were put into the crucible which was preheated and then it was kept for melting in the furnace. Molten metal was heated to 800^{o}C. Degassing was carried out by adding chloromethane to remove hydrogen from the molten metal in order to avoid the void formation during solidification. The pre-heated E-Glass fibers and fly ash particles were then added into the crucible and by using a mechanical stirrer it was thoroughly mixed and then poured into a preheated die. The melt is then allowed to solidify in the die. The different castings were obtained in the same way by varying the compositions as given in the table-1. The cast specimens were machined according to the ISO 1608 standards and then they were subjected to thermal treatment (solution heat treatment with water quench). Test samples were solutionised in a heat treatment furnace for a temperature of 520^{o}C. After solutionsing the samples were immediately quenched in water at room temperature and aged for 1, 3 and 5 hours respectively.

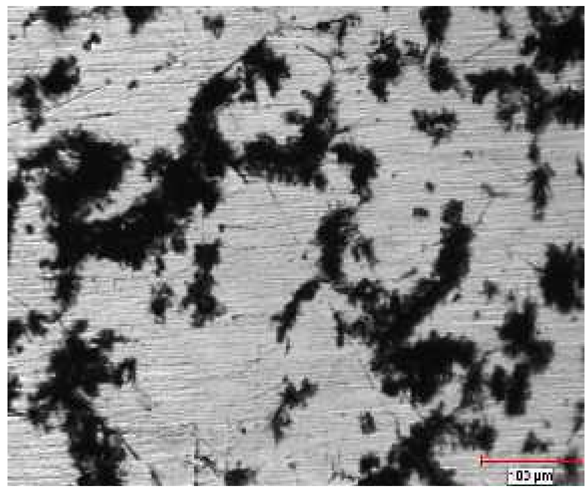
Fig. 1: Electric resistance furnace

2.1 Metallographic Studies

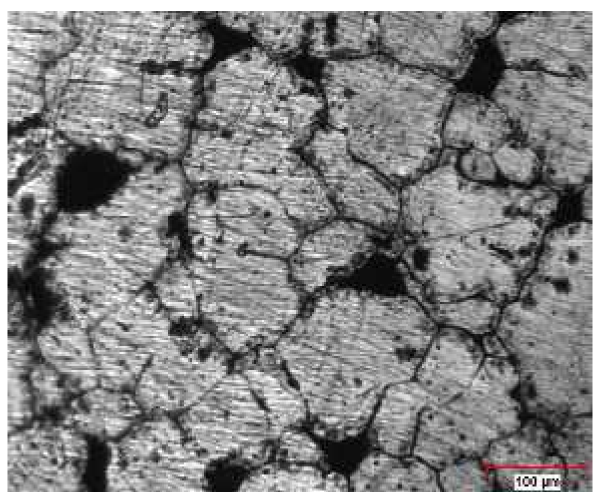
Table 1: Casting compositions (weight in %)

Sl. No.	%Fly ash	% E-Glass	% Al 7075
C_1	1	1	98 (2.5 kg)
C_2	1	2	97
C_3	1	3	96
C_4	2	1	97
C_5	2	2	96
C_6	2	3	95
C_7	3	1	96
C_8	3	2	95
C_9	3	3	94
C_{10}	No reinforcements		100

Microstructure observations have been done with the aid of a metallurgical microscope to obtain some qualitative evidences on the combined fly ash, E-Glass particulate distribution in the alloy matrix, bonding quality between two particulates and the matrix. The samples were viewed at different magnifications and photomicrographs shown in Fig. 2 were captured to predict the confirmation of the presence of two particulates in the alloy matrix. It is found that the distribution of reinforcements in the matrix is uniform. The alloy matrix grains are finer and the bonding between particulate surface and the matrix material is satisfactory. No interfacial reaction products are observed superficially.



C_1



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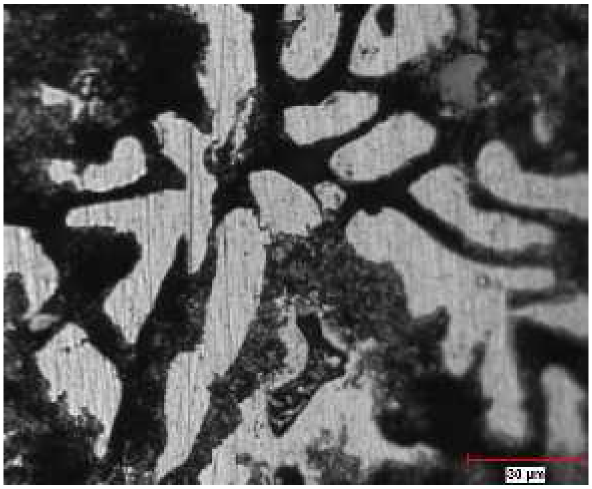
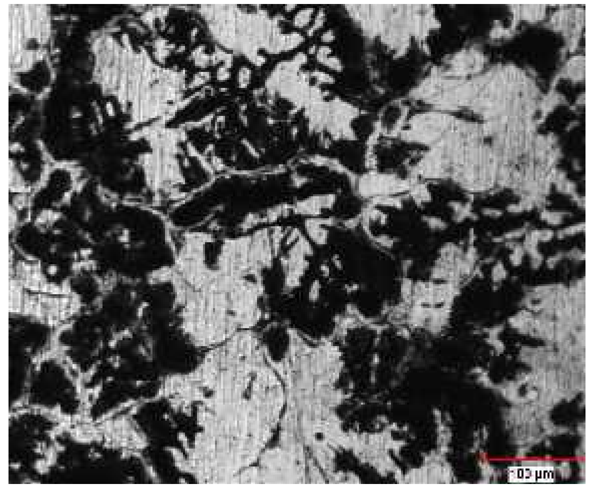
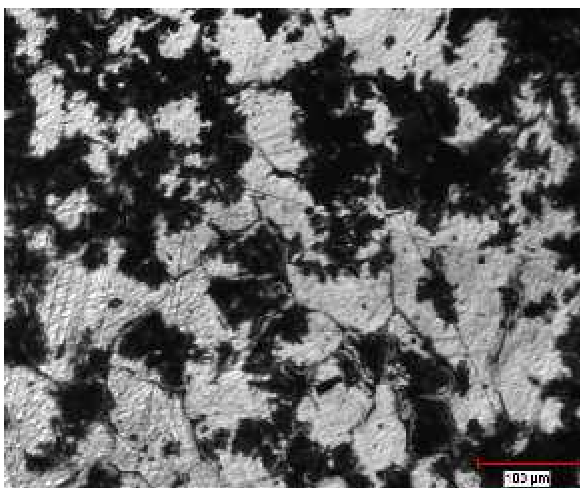


C_3

C_5

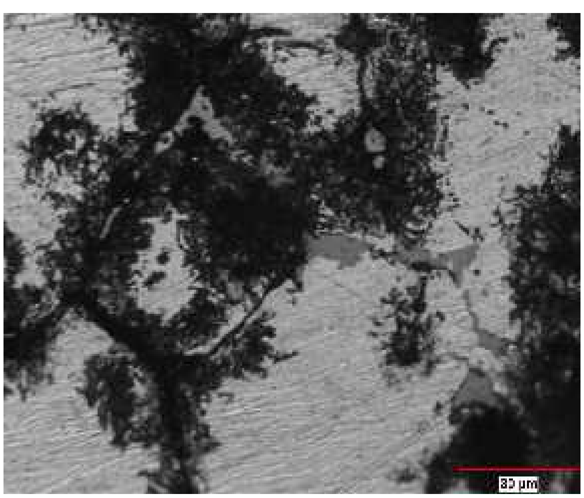


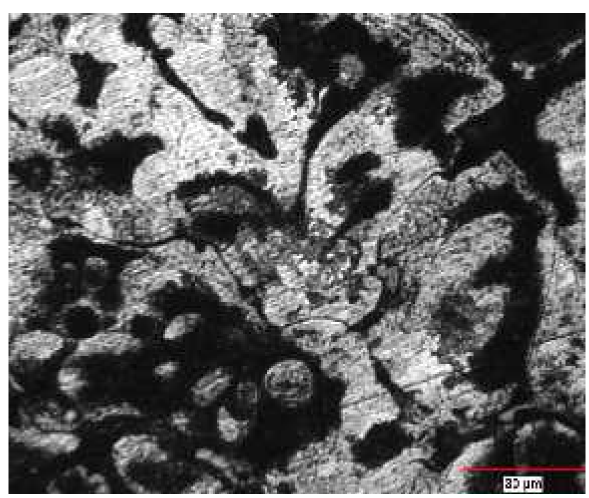
C_6



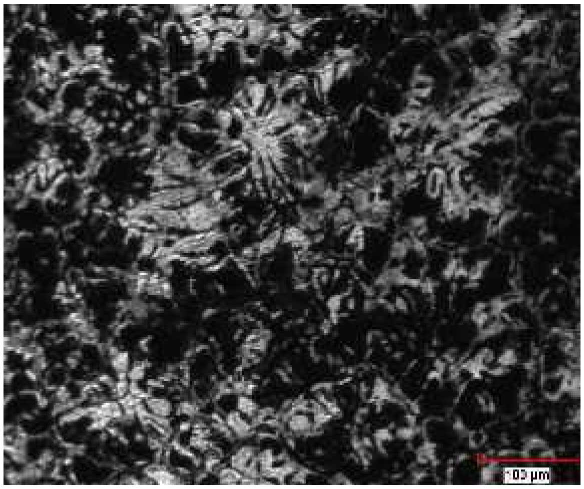
C_4

C_7

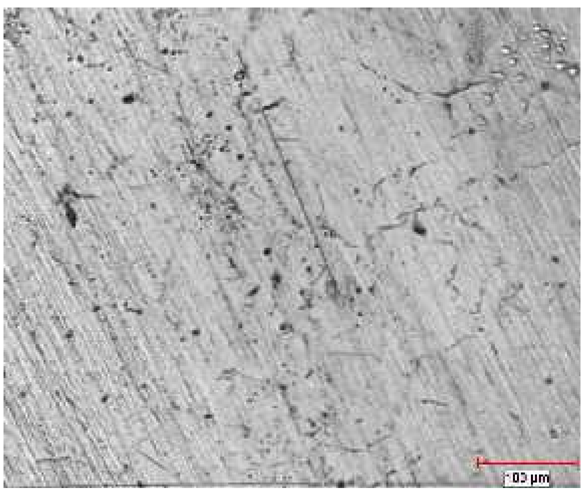




C_8



C_9

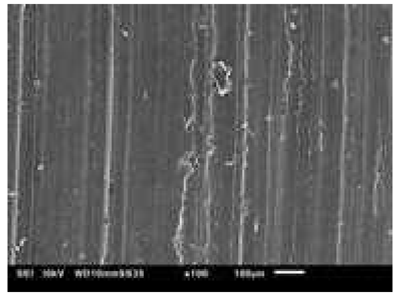


C_{10}

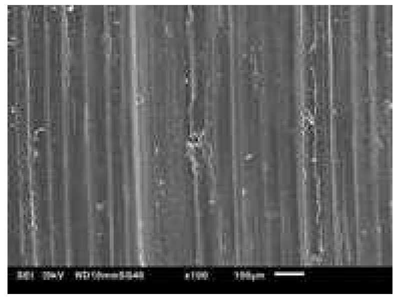
Fig. 2: Microstructure of different compositions

The microstructure of MMCs was observed under a Scanning Electron Microscope (SEM) at various locations across the specimen to examine the distribution of reinforcements in the matrix. Fig. 3 shows SEM images of composites displaying a good bonding between matrix and reinforcements.

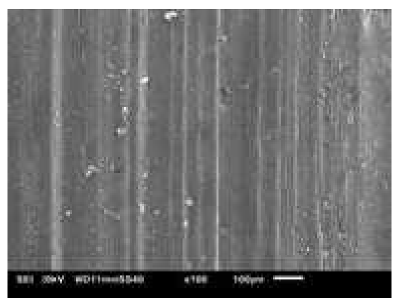
a) As cast



b) 1 hour aging



c) 3 hrs. aging



d) 5 hrs. aging

Fig 3: SEM of C_5 specimen

3. HARDNESS TEST

Hardness tests were conducted on as cast and heat treated composites to know the effect of fly ash and E-glass on the matrix material. The polished specimens were tested using Brinell's hardness testing machine. A load of 60 kg for a period of 10 seconds was applied on specimens. The indenter has a diameter of 2.5". The indentation diameter on testing specimen was measured using optical microscope. The test was carried out at three different locations and the average value was taken as the hardness of the composites at various conditions. The values are tabulated in Table 2.

Hardness calculation

Brinnell's Hardness Number is calculated by using

$$BHN = \frac{P}{\left(\frac{\pi D}{2}\right)\times\left(D-\sqrt{D^2-d^2}\right)}$$

P= Load (60 kg)
D= indenter diameter (2.5mm)
d= surface indentation diameter

Table 2: Hardness (BHN) of specimens at different conditions.

Sample designation	As Cast	1-hr aging	3-hr aging	5-hr aging
Plain	75	80	90	100
C_1	77	82	85	90
C_2	86	87	92	94
C_3	98	101	106	107
C_4	107	109	112	113
C_5	117	118	122	124
C_6	120	124	127	126
C_7	135	137	140	141
C_8	138	141	144	145
C_9	140	146	150	152

4. RESULTS AND DISCUSSIONS

Hardness tests were performed on as cast and composites to know the effect of the reinforcements and heat treatment. The polished specimens were tested as per ASTM E10 standards and the values are tabulated, plotted as shown in Figures 4,5 & 6. From the figures it is evident that the hardnes of the composite material is much higher than the parent material. Also, the hardness of the composite material increases with wt. % of reinforcements and heat treatment. This may be attributed due to the presence of hard fly ash particulates and E-glass fibers.

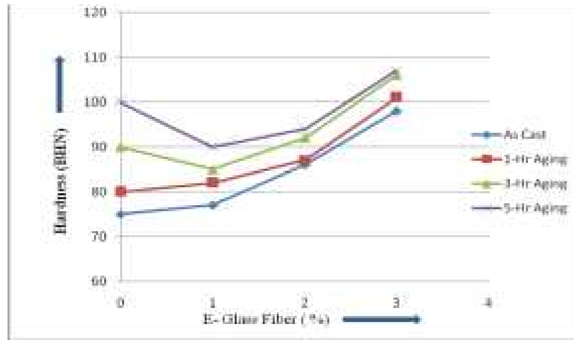


Fig. 4: Effect of variation of E-Glass Fiber on hardness value with constant fly ash content (1%)

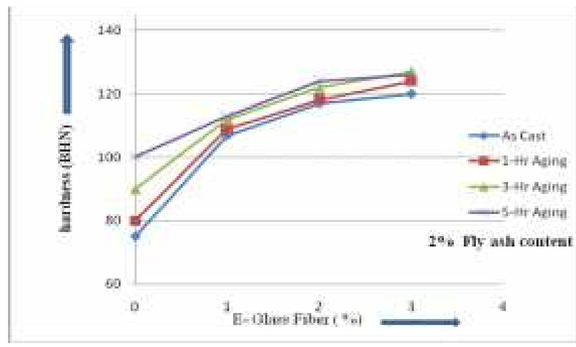


Fig. 5: Effect of variation of E-Glass Fiber on hardness value with constant fly ash content (2%)

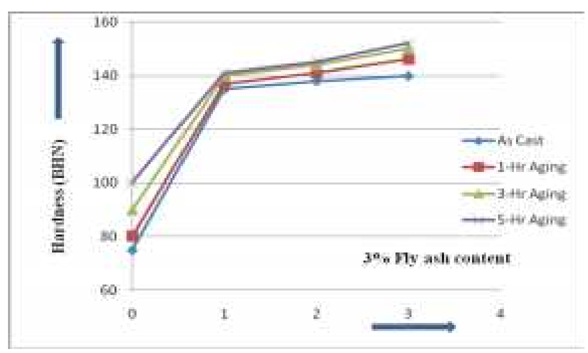


Fig. 6: Effect of variation of E-Glass Fiber on hardness value with constant fly ash content (3%)

5. CONCLUSIONS

Based on the experimental investigation carried out on the fly ash, E-glass reinforcements with Al 7075 as matrix material, the following conclusions are made:

- Using stir casting method, fly ash particulates and E-glass fiber can be successfully introduced in the

Al 7075 matrix alloy material to fabricate hybrid composite material.

- From the microstructure analysis, it is evident that the composites fabricated have fairly even distribution of reinforcements in them.
- The hardness of the composite material has increased with increase in weight % of fly ash, E-glass fibers.
- Hardness of heat treated composites is higher when compared to as cast composite.
- The MMC formed is superior to Al 7075 alloy, with almost same density as that of the individual.

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