Tensile strength 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-7010 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 %).

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 tensile 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-7010 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 7010 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

2.1 Stir Casting Method

This involves incorporation of particulate into liquid aluminium melt and allowing the mixture to solidify. Here, the crucial thing is to create good wetting between the particulate reinforcement and the liquid aluminium alloy melt. The simplest and most commercially used technique is known as vortex technique or stir-casting technique. The vortex technique involves the introduction of pretreated ceramic particles into the vortex of molten alloy created by the rotating impeller. Lloyd (1999) has reports that vortex-mixing technique for the preparation of ceramic particle dispersed aluminium matrix composites was originally developed by Surappa& Rohatgi (1981) at the Indian Institute of Science, Bangalore. Subsequently several aluminium companies further refined and modified the process which is currently employed to manufacture a variety of aluminium metal matrix composites on commercial scale.

The vortex method is one of the better known approaches used to create and maintain a good distribution of the reinforcement material in the matrix alloy. In this method, after the matrix material is melted, it is stirred vigorously to form a vortex at the surface of the melt, and the reinforcement material is then introduced at the side of the vortex. The stirring is continued for a few minutes before the slurry is cast. There are different designs of mechanical stirrers. Among them, the turbine stirrer is quite popular. During stir casting for the synthesis of composites, stirring helps in two ways: (a) transferring particles into the liquid metal, and (b) maintaining the particles in a state of suspension.

2. 2 SPECIMEN PREPARATION:

The matrix material for this experimental investigation is aluminum AA7010 in the form of ingots(Fig.2). The reinforcements are fly ash particulates in the range of 0.1 to 100 μm(Fig.3) and E-Glass short fibers of length 2 to 3 mm(Fig.4) .The hybrid composite is formed by stir casting method. An electric resistance furnace was used for melting the alloy(Fig 1) . 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 ASTM 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

Fig.2:Al alloys -7010

Fig.3:Fly ash

Fig.4:E-glass short fibre

Table 1: Casting compositions (weight in %)

Sl. No.	%Fly ash	% E-Glass	% Al 7010
A1	1	1	98 (2.5 kg)
A2	1	2	97
A3	1	3	96
A4	2	1	97
A5	2	2	96
A6	2	3	95
A7	3	1	96
A8	3	2	95
A9	3	3	94
PLAIN	No reinforcements		100

3. RESULTS AND DISCUSSION

3.1:Tensile test:

Test specimens were prepared according to ASTM 1608 standards shows in figure3.1. and then they were subjected to thermal treatment (solution heat treatment 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.

The specimen was loaded in Universal Testing Machine until the failure of the specimen occurs. Tests were conducted with different combinations of reinforcing materials and ultimate tensile strength and area of elongation 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 extensometer is attached. Simultaneous readings of load and elongation are taken at uniform intervals of load. Uniaxial tensile test is conducted with gradual increasing loading condition

Fig5 :Tensile specimen

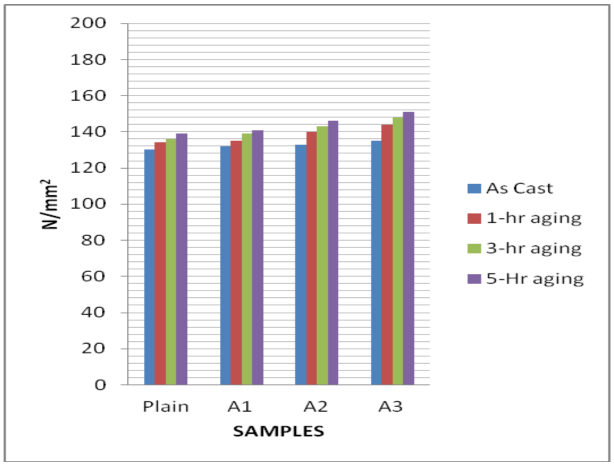
The fine finished tensile specimens subjected to digitalized universal testing machine, shown in fig 5. Both the ends are fixed on the holding jaws of the machine and the tensile load is applied gradually on the specimen until it breaks. The obtained ultimate tensile strength values are listed in table2.

Fig. 6: UNIVERSAL TESTING MACHINE

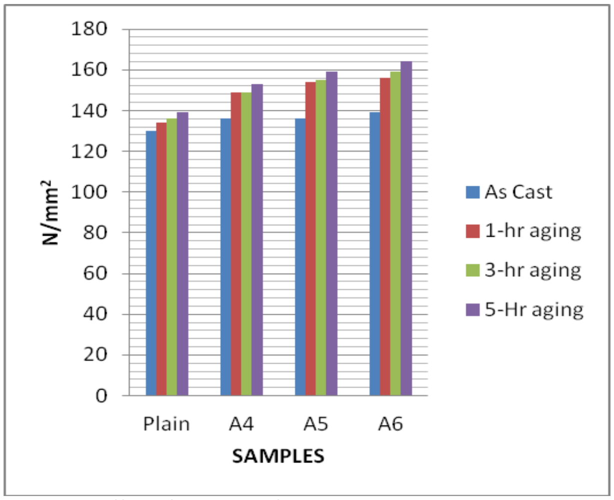
Table 2 : Results of Tensile strength test

Sample designation	As Cast (N/mm^2)	1-hr aging (N/mm^2)	3-hr aging (N/mm^2)	5-Hr aging (N/mm^2)
Plain	130	134	136	139
A1	132	135	139	141
A2	133	140	143	146
A3	135	144	148	151
A4	136	149	149	153
A5	136	154	155	159
A6	139	156	159	164
A7	145	160	162	166
A8	148	162	167	170
A9	150	161	169	172

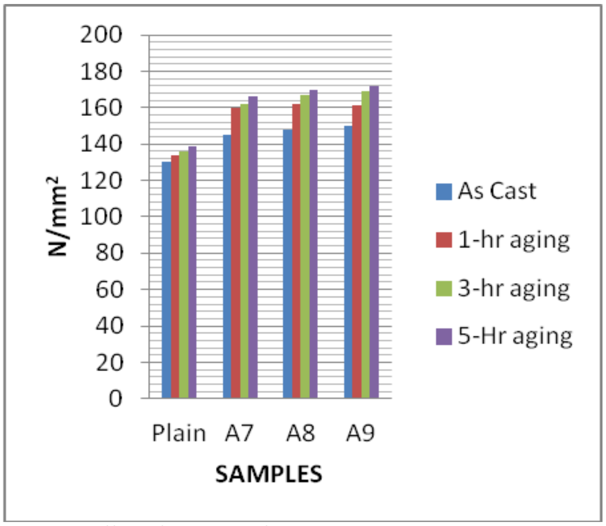
The below graphs showed that the tensile strength is more in A9 composition of 5-Hour aged specimen.



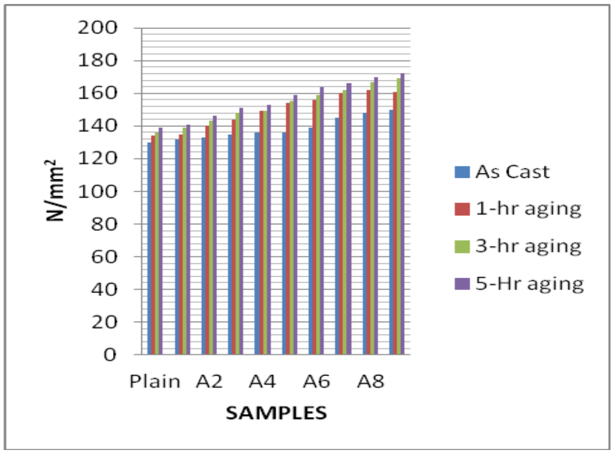
Graph 1: Effect of variation of E-Glass Fiber on hardness value with constant fly ash content (1%)



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



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



Graph 4: Effect of variation of E-Glass Fiber and fly ash content on tensile strength

From the above graphs it is evident that the hardness and tensile strength of the composite material is much higher than that of its parent metal. It is also shown that the hardness and tensile strength of the composite material increases with wt% of fly ash and E-glass content. This may be attributed to the addition of reinforcement makes the ductile Al7070 alloy into more brittle and hard as silica content increases. And also the heat treatment and aging lead to the formation of inter metallic precipitates. From the graphs it is very clear that 5 hours aging specimen shows better hardness and tensile strength as compared to other specimens.

4. CONCLUSION

Based on the experimental investigation carried out on composites containing the fly ash E-glass reinforcement with Al7010 as the matrix material, the following conclusions are made.

- Using stir casting method, fly ash particulate and E-glass short fiber can be successfully introduced in the Al7010 alloy to fabricate hybrid composite material.
- However, with more than 3% weight fraction of fly ash particulate was difficult to form the composite due to stirring process
- 5 hours aged specimens shows better results as inter metallic bonding is denser than the other specimens.
- The MMC formed is superior to Al 7010 alloy, with almost same density as that of the individual.
- Tensile strength of reinforced and heat treated composites is higher compared to as cast composite.

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