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Effect of Fly Ash on Mechanical Properties of Aluminum Alloy

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Abstract— This paper presents the effect of fly ash as reinforcement on mechanical behavior of aluminum alloy. 5% by weight of untreated fly ash was used as a reinforcement to fabricate the composite samples by sand casting technique. Tensile, Hardness and Fatigue tests were carried out for the samples. It has been observed that by the addition of fly ash to aluminum alloy improves the ultimate tensile strength (UTS) and hardness by 15.87% and 5.64% repectively as compared to sand casted simple aluminum alloy.Similarly fatigue tests reveal that fly ash reinforced aluminum composite has greater fatigue life than the unreinforced aluminum alloy.

Keywords— aluminum alloy, sand casting, aluminum composite, mechanical behavior, strength

I. Introduction

Composite is the combination of two elements or constituents. The constituents have different composition and they retain their insolubility in each other. There are various types of composites in which they are classified. Most common classes are particulate reinforced composite and fiber reinforced composite. In particulate composite the reinforcement material is in the form of particles and in the fiber reinforced composite the reinforcement is in the form of fiber having some length and width or diameter. It is the need of the day to develop, design and fabricate new type of materials having the desired physical, chemical and mechanical properties for the specific application. Most recent trend in material field is discovering of new materials having low cost, excellent performance and lightweight and good mechanical properties. Combining reinforcement with the suitable matrix metal to achieve excellent properties has become a remarkable area for manufacturing science in MMCs [1]. The family of metal matrix composites (MMCs) has got more attention amongst various categories of composites. This class of composites is most commonly used in automobile and aerospace industries [2]. Pradeep R et.al carried out the study of a composite fabricated from aluminum alloy, silicon carbide and red mud. Al 7075 with different proportion of SiC and red mud were used. Samples were prepared for mechanical characterization having different composition. After performing mechanical tests it was observed that the tensile strength and Hardness enhanced as compared to the unreinforced aluminum alloy [3]. Ravichandran M et.al synthesized a composite by combining titanium dioxide (TiO_2) with pure aluminum element. He prepared various samples of the composite. The amount of TiO_2 varied during the fabrication of composite. He performed micro structural analysis for the presence of TiO_2 as reinforcement. He also performed mechanical tests (hardness, tensile) on the samples to compare the hardness and tensile strength of the composite with the pure aluminum. Finally it was concluded that by using 5% of TiO_2 with pure aluminum causes enhancement in the hardness and tensile strength [4]. Keshavamurthy R et. al performed work on the mechanical behavior of Al7075-TiB_2. For this purpose he took two master alloys having designation as Al -10%Ti and Al-3%Br. Micro structural study of the composite and master alloys carried out. Also mechanical tests were performed for the identification of the mechanical behavior of the composite and the alloys. The results obtained from the tests showed that tensile strength, hardness of the fabricated composite are higher than the alloy [5].Uvaraja et .al used the concept of hybridization while designing a composite by combining aluminum, silicon carbide and boron tetra carbide. The hybrid material has good fatigue properties, greater strength, dimensional stability at elevated temperatures, high wear resistance and lighter weight [6,7]. Mahendra Boopathi et al investigated the physical/mechanical properties of Aluminum 2024 in the presence of silicon carbide, fly ash and its combinations. The composites fabricated with the SiC (5%) + fly ash (10%) + Al2024 and SiC (10%) + fly ash (10%) + Al2024 compositions were studied.The various tests carried out on these hybrid samples reveal that by the addition of silicon carbide and fly ash the hardness of the hybrid composite increases while the density decreases. Similarly tensile strength of hybrid composite increases while elongation produced in the samples decreases with the addition of reinforcements [8]. A. K. Senapati et al fabricated Aluminum Matrix Composites (AMCs) using waste fly ash obtained from thermal power plant as reinforced material. He used 14.3% by volume of the reinforcement material (untreated fly ash) with aluminum. Also he used 13.2% by volume of fly ash (treated thermally). It was concluded that mechanical properties of treated fly ash reinforced composite are better than the untreated fly ash composite [9]. J. Babu Rao et al took pure aluminum and used five to fifteen (5%- 15%) percent by weight fly ash as reinforcement. Both X-ray Diffraction

(XRD) and Scanning Electron Microscopy (SEM) were used for the identification of the phase presence and for the analysis of microstructure of the fly ash as well as the aluminum-fly ash composite. By the addition of fly ash as reinforcement compression strength and hardness increased while the density of the composite decreased [10].

II. MATERIALS AND METHODS

Addressing the call of the day for enhanced mechanical properties it is required to use inexpensive and readily available constituents in metal matrix. Various materials that are waste or byproducts can be explored in this regard and their potential to support and develop new combinations may be explored. In the current research aluminum alloy and fly ash were used as a matrix material and reinforcement respectively.

A. Aluminum Alloy

Aluminum alloy was used as a matrix material. Aluminum alloy composition was checked through elemental analysis technique. The test result for elemental composition has shown in the Table 1 given below.

TABLE 1: ELEMENTAL COMPOSITION OF Al ALLOY

Element	**% by weight**
Al	82.71
Si	12.54
Cu	2.57
Fe	0.799
Zn	0.65
Mg	0.263
Mn	0.255
Ni	0.078
Sn	0.026

B. Fly Ash

Fly ash was used as a reinforcement material. Elemental composition analysis was also carried out for it. The chemistry is given in the following Table 2.

TABLE 2: FLY ASH COMPOSITION

Element	**% by weight**
C	16.65
O	48.75
Mg	1.07
Al	9.11
Si	13.48
P	0.65
S	0.37
K	0.98
Ca	4.62
Ti	0.50
Fe	3.80

C. Sand Casting of Composite

Once the composition was identified for both the matrix as well as reinforcement material, next step is to mix these two materials in proper way to fabricate a compsite.5% by weight fly ash was used with aluminium alloy to fabricate the aluminium based composite. Sand cating was used as a manufacturing technique for the fabrication of the composite. The steps mentioned in Fig 1 were followed.

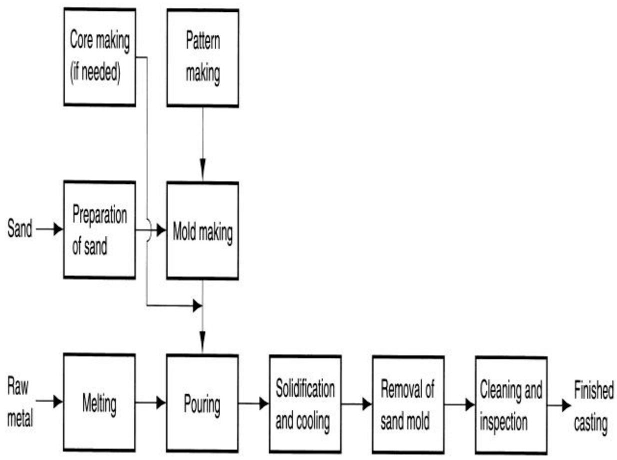


Figure 1: Activities in sand casting

Figure 2: Mould for fabrication of samples

Figure 3: Preparation of composite

Figure 4: Pit Furnace for Alloy melting

D. Tensile Test Conduction

The most common test usually used to find the tensile strength/stress of materials. This test is performed on ultimate tensile testing machine shown in Fig 5. Ultimate tensile testing machine has both facilities either to find tensile or compressive strength of the material. Tensile tests were carried out to draw the stress-strain curve on the computer. Standard sample sizes were used during the experiments as per requirement of the machine. Two types of samples were used to predict the tensile behaviour. First samples of unreinforced/ simple aluminium alloy were tested and stress-strain graphs were generated. Similarly keeping the same condition aluminium based matrix composite samples tested also and stress-strain curves were produced.

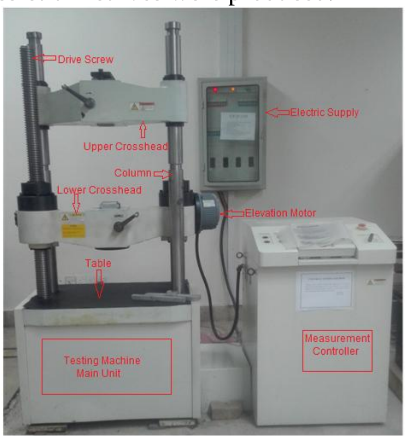


Figure 5: Ultimate Tensile Testing Machine

E. Fatigue Test Conduction

When a mechanical component is subjected to cyclic load it is more unsafe than the situation in which static load is applied. Samples for simple aluminium alloy and aluminium based matrix composite both were tested using fatigue testing machine as shown in Fig 6. During the experiments endurance N and time were noted.

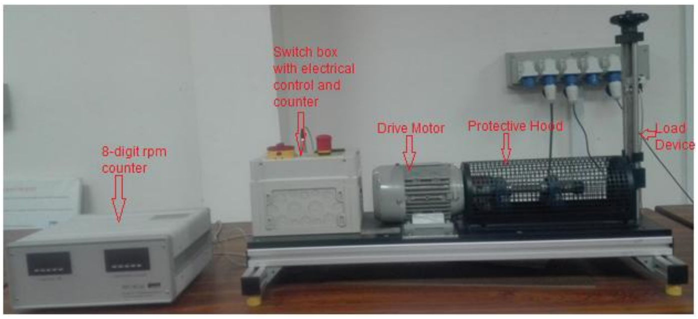


Figure 6: Machine for Fatigue Test

F. Hardness Test conduction

Hardness test is a non-destructive test which is mostly used due to its simplicity.There are four types of hardness machines available to check the hardness value of a material namely, Brinell, Rockwell, Micro Vicker and Vicker hardness testers. We have used Vicker hardness tester as shown in Fig 7 in our experiments. Just like for the tensile and fatigue tests samples were also fabricated for hardness tests. First the hardness value for unreinforced aluminum alloy was found. Secondly the hardness value for the aluminum based composite material was calculated. The test technique is same as Brinell’s hardness test but unlike the Brinell’s technique, a pyramid-shape diamond is used in the experiment for indentation. The diagonals of the impression are measured and then average of both is taken to find the hardness value of the material.

Figure 7: Machine for Hardness Test

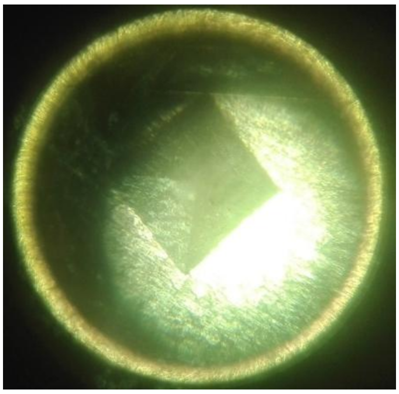
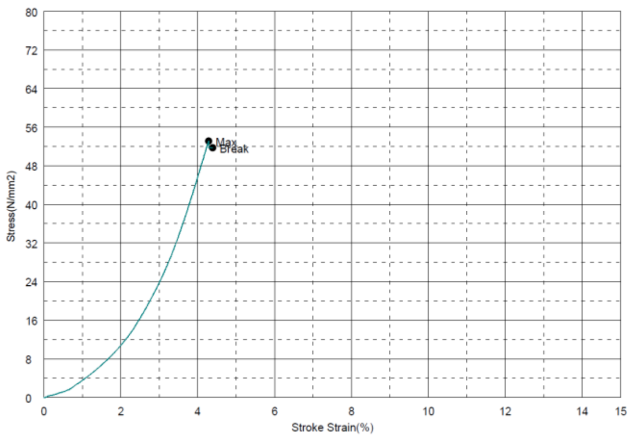


Figure 8: Impression produced during hardness test

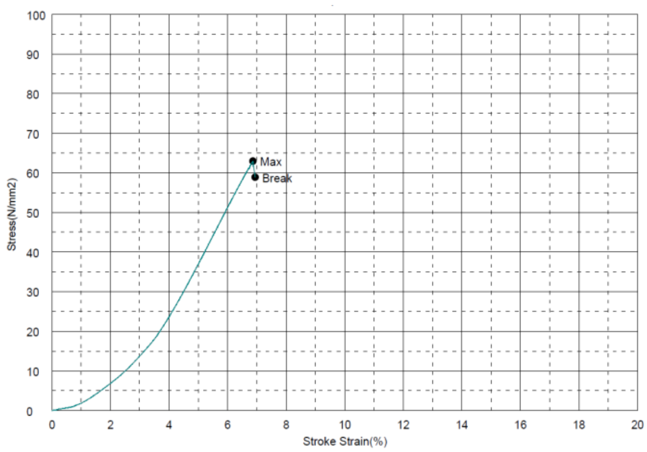
III. EXPERIMENTAL RESULTS

A. Tensile Test Results

The tensile tests results for unreinforced/simple aluminum alloy and luminum based matrix composite are presented in the Graph 1 and Graph 2 respectively.



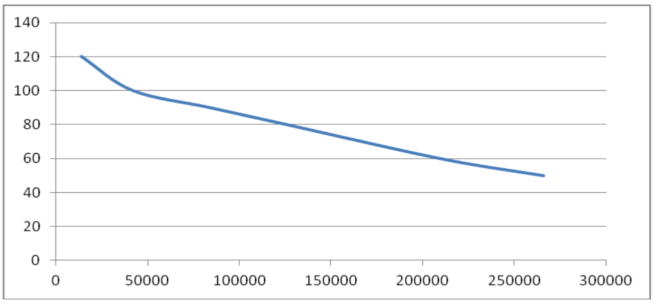
Graph 1: Simple aluminum alloy stress-strain curve



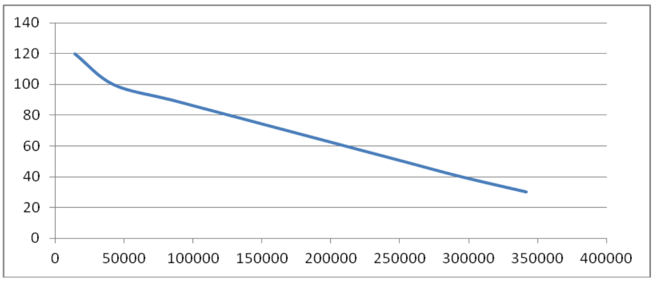
Graph 2: Aluminum based matrix composite stress-strain curve

B. Results of Fatigue Test

The fatigue tests results for unreinforced/simple aluminum alloy and luminum based matrix composite are presented in the Graph 3 and Graph 4 respectively.



Graph 3: S-N curve for sand casted simple aluminum alloy



Graph 4: S-N curve for sand casted aluminum based matrix composite

C. Results of Hardness Test

The hardness tests results for unreinforced/simple aluminum alloy and luminum based matrix composite are presented in the Table 3 and Table 4 respectively.

TABLE 3: TEST FOR UNREINFORCED ALUMINUM ALLOY

Force (Kgf)	**Force (N)**	**Dwell Time (sec)**	**d_1 (mm)**	**d_2 (mm)**	**$d = d_1 + d_2/2$ (mm)**	**VHN**
5	49.03	5	0.310	0.314	0.3120	95.3

TABLE 4: TEST FOR 5% FLY ASH REINFORCED ALUMINUM BASED MATRIX COMPOSITE

Force (Kgf)	**Force (N)**	**Dwell Time (sec)**	**d_1 (mm)**	**d_2 (mm)**	**$d = d_1 + d_2/2$ (mm)**	**VHN**
5	49.03	5	0.302	0.304	0.303	101

CONCLUSION

Mechanical behaviour of sand casted simple aluminium alloy and aluminium based composte were presented in this work. By performing various types of tests; tensile, fatigue and hardness it has been observed that mechanical properties are improved. The ultimate tensile strength (UTS) of the sand casted aluminum based composite improves by 15.87% as compared to sand casted simple aluminum alloy.The fatigue strength of the sand casted aluminum based composite increases as compared to simple aluminum alloy The hardness of the sand casted aluminum based composite increases by 5.64% compared to simple aluminum alloy.

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