Fabrication and Characterization of Aluminium 7075 - Flyash Metal Matrix Composite with Analytical Verification on Application to Aircraft Wings

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Abstract: *The need for high strength and light weight materials is the need of the day in all fields of applied sciences. This research work concentrates on the fabrication of a light weight material by adding flyash to Aluminium 7075, thus forming a metal matrix composite. Different test pieces are fabricated by varying the percentage composition of flyash. Characterisation shows that as the percentage composition of flyash increases the weight of the material comes down but the strength increases. Hence aluminium flyash composite is seen as a prospective candidate for the fabrication of aircraft wings which requires high strength to weight ratio. Using Aluminium flyash metal matrix composite an unmanned aerial vehicle wing is modelled and analysed. The properties of the material were obtained from the experiments conducted on the best specimen of the fabricated composite pieces. The results are compared with the wings modelled using aluminium 7075 metal alloy. It is found that the strength of both the metal alloy and the composite are almost similar where as the composite has an advantage of lower weight than the metal alloy.*

Keywords: *Metal matrix composite 1, mechanical properties 2, Aluminium 7075 3, aircraft wings 4.*

1. BACKGROUND

The bloom of aerospace industries in the 1990s paved the way for many researches in the development of light weight materials for aerospace applications. Recently numerous studies have been carried out for developing a low cost aluminium metal matrix composite [1]. Flyash is chosen as the reinforcing material for the composite as flyash is a light weight material produced abundantly every year in India as a residue after the combustion of coal during power generation. Different methods such as stir casting method, powder metallurgy method, ultrasonic assisted casting [2], [8], [11] etc., are the different types of fabrication techniques available for metal matrix composites. In stir casting method the properties of Al metal matrix composite produced by stir casting method have high strength than the composites produced by powder metallurgy technique. Based on the studies conducted earlier it is observed that mechanical strength of aluminium flyash metal matrix composite increases with the increase in percentage composition of flyash [17]. In addition to the above histories this research work also finds an application in the field of aerospace structure[12] with aluminium flyash composite being a potential light weight material of higher strength

1.1 Aim

With the studies carried out on the available literatures an attempt has been made to fabricate aluminium flash metal matrix composite material using stir casting method and to investigate its mechanical properties by varying the fly ash composition. This research also concentrates on the application of aluminium composite for aerospace structures by modelling an aircraft wing using the results obtained and comparing it with the wing fabricated using aluminium alloy.

2. FABRICATION OF AL – FLYASH COMPOSITE

The Al - fly ash metal matrix material was stir casted in the form of desired shape and size by adding Fly Ash and Activated Carbon as reinforcements by various weight percentages[2]. The casted specimen were rapidly cooled to room temperature by knocking them out from the mold after few minutes of casting. The test specimens were prepared by machining the casted materials under ASTM standards.

Table 1: *Composition of Fly ash , Act. Carbon, AL 7075*

Specimen No.	*Fly Ash*	*Act. Carbon*	*Al-7075*
Specimen 1	5%	1%	94%
Specimen 2	10%	2%	88%
Specimen 3	15%	3%	82%

2.1 Experimental Testing of Mechanical Properties

A set of tests including tensile test, density test, hardness test, impact test were done for finding out the properties[4]. All the tests were carried out in room temperature with ASTM standards. Tensile test is carried out with ASTM E8/82 standard in UTM machine. The Percentage of Elongation, Percentage of Reduction in Area, Young's Modulus and Ultimate Tensile Strength were measured. Figure 1 shows the specimens used for tensile test and Figure 2 shows the decrease in percentage of elongation with increase in addition of Fly Ash. The Charpy impact test / Charpy V-notch test, is a standardized high strain-rate test which determines the amount of energy absorbed by material during fracture. Figure 3 shows the specimen used for Charpy tests. Brinhell hardness test and Rockwell hardness test was conducted on each specimen. The hardness of the specimen id estimated using th standard equations

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

P= Applied force kgf

D= Diameter of indenter mm

d= Diameter of indentation mm

The increase in hardness is shown in Figure 4. Density of all the specimens were found out to study the implication on weight reduction by adding fly ash. The density is estimated using the following expression

$$\rho = \frac{\text{weight in air}}{(\text{weight in air - weight in water})} \times \rho_{water}$$

Scanning Electron Microscope (SEM) was used to analyze the detail surface information of all compositions, orientation of particles, distribution of particles mixed, etc and the images are shown in Figure 5,6 and 7.

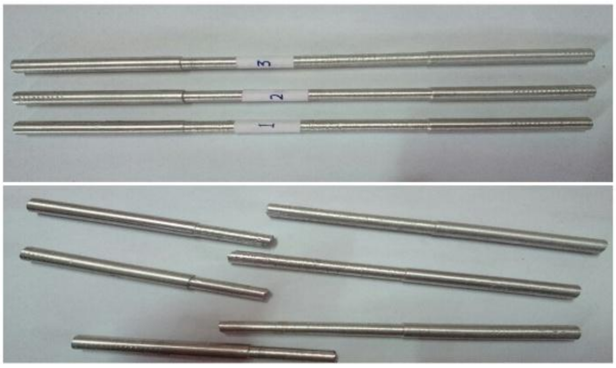

Fig 1: *Specimens used for tensile test*

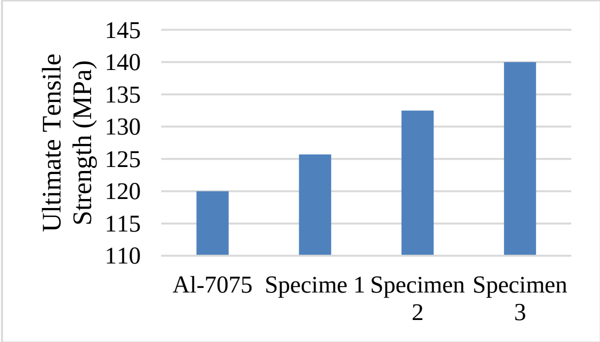

Fig 2: *Results of tensile test*

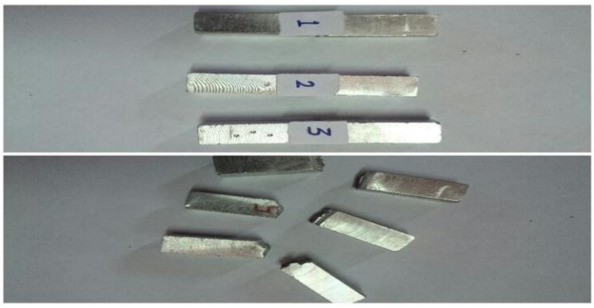

Fig 3: *Specimens used for Charpy test*

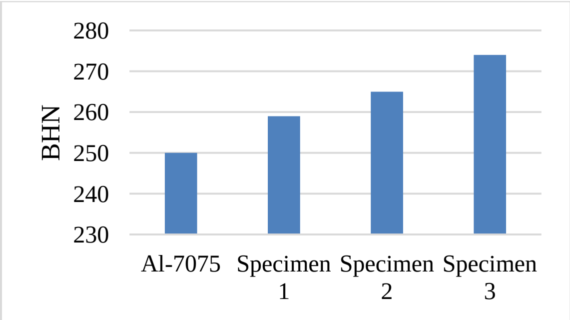

Fig 4: *Results of Brinhell hardness test*

Fig 5: *SEM image of specimen 1 at X5000*

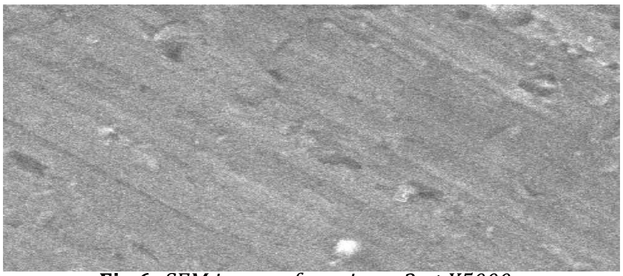

Fig 6: *SEM image of specimen 2 at X5000*

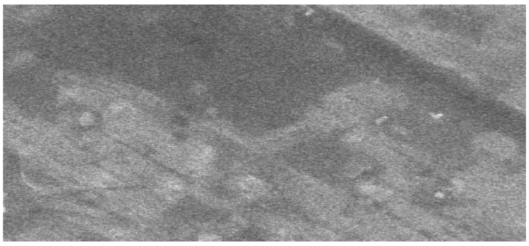

Fig 7: *SEM image of specimen 3 at X5000*

3. MODELLING OF AIRCRAFT WING

The wing of an UAV is modeled[28] using Catia V5 R20 and Ansys 14.5. The wing consist of 2 spars and 9 ribs. 9 ribs of which 8 ribs which measures 15 mm wide and 1.2 mm thickness and 1 rib at middle which measures 40 mm wide and 2 mm thickness. From the conclusion of experimental results specimen 3 shows the best property than the base metal. So, specimen 3 and base metal are applied over the wing structure and analyzed at both material condition. After the analysis the results for both the Specimen 3 material and the base material are compared. The properties of both the Al 7075 base material and composite material are shown in Table 2.

Table 2: *Properties of Al alloy and composite metal for analysis*

Material	*Young's Modulus Pa*	*Poisson's Ratio*	*Bulk Modulus Pa*	*Shear Modulus Pa*
Al 7075	71700	0.33	70294	26955
Al composite	77470	0.3	64558	29796

3.1 Analysis of Aircraft Wing

Finite Element Analysis Software Ansys 14.5 is used for the analysis of the wing structure[26], [27]. The wing of the UAV is analyzed by applying a uniformly distributed load 0.982 kg/mm and applied at tip side of wing structure. The maximum deformation in the base material and in specimen 3 is shown in Figure 8 and Figure 9.

Table 3: *Experimental Results*

Properties	*Al composite*	*Al 7075*
Equivalent Von-Misses Stress	9518.6 N/m²	9425.9 N/m².
Equivalent Elastic Strain	0.18118	0.19271.
Total Deformation	0.021 m	0.022 m.

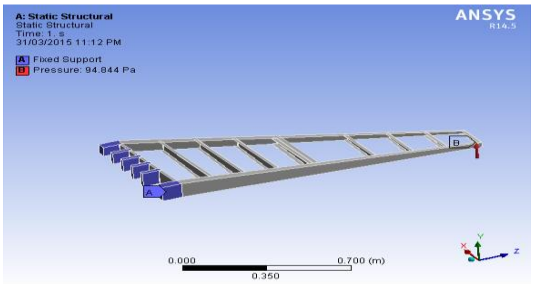

Fig 8: *Modelling of wing structure and load applied*

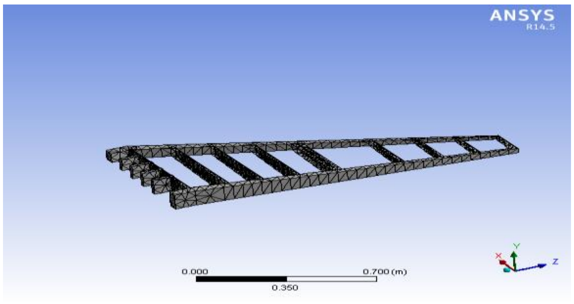

Fig 9: *Meshing of wing model*

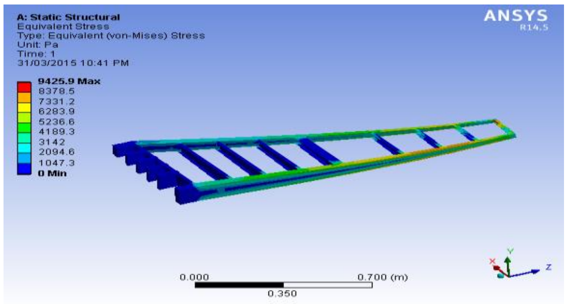

Fig 10: *Equivalent Von-Misses Stress of Al 7075 wing*

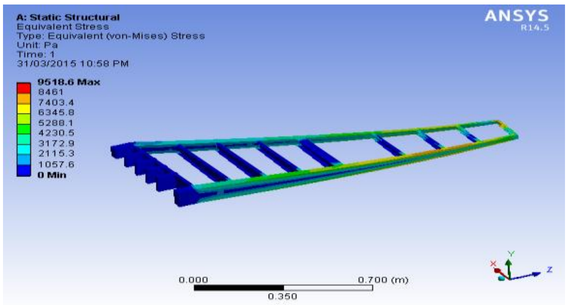

Fig 11: *Equivalent Von-Misses Stress of composite wing*

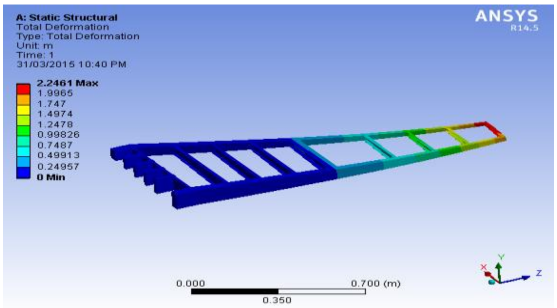

Fig 12: *Maximum deformation of Al7075 wing*

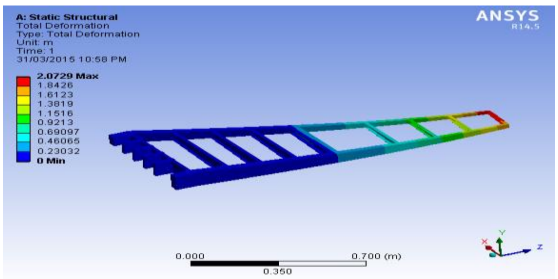

Fig 13: *Maximum deformation of composite wing*

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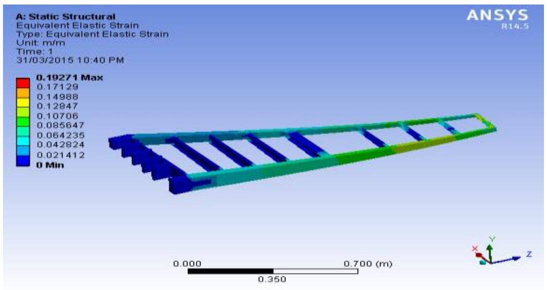

Fig14: *Maximum strain on Al7075 wing*

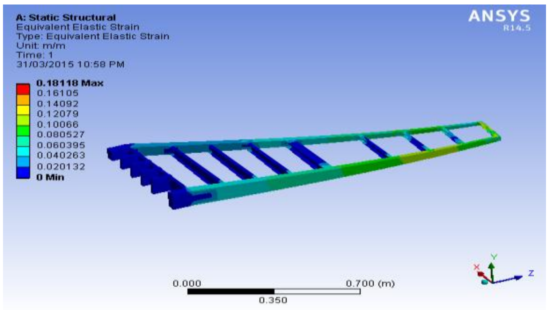

Fig 15: *Maximum strain on composite wing*

4. RESULTS AND DISCUSSION

From the experimental results it is observed that the mechanical properties of Al-7075 increases with the increase in amount of Fly Ash and Activated Carbon percentages. With increase in above particles, the Hardness, Young's Modulus, Toughness Value and tensile strength were increased compared to the base metal and the density, % of Elongation and % of reduction in Area got decreased in third specimen. The results of the experimental tests carried out is shown in Table 3 and the results of the computational analysis is shown in Table 4. From the analysis result it is clear that the wing with specimen 3 can withstand more stress with low strain and deformation than the wing with Al 7075.

Table 4: *Analytical Results*

Specimen No.	*Ultimate Tensile Strength (MPa)*	*Young's Modulus (GPa)*	*Density (g/cc)*	*Charpy Impact Test (J)*	*Brinell Hardness Number (BHN)*	*Rockwell Hardness Number (RHN)*
Al-7075	120.0	70.00	2.810	1	B250	R55
Specimen 1	125.7	73.55	2.789	1	B259	R58
Specimen 2	132.5	75.51	2.696	2	B265	R63
Specimen 3	140.3	77.47	2.566	2	B274	R66

4.1 Conclusions

Aluminium – fly ash metal matrix composites were effectively fabricated by stir casting process with homogenous distribution of fly ash particles in the matrix. To improve the adsorption properties and to increase the workability, activated carbon was added during the fabrication of the composite.

Based on the experimental observations the following conclusions have been drawn.

1. The density of the composites reduces with increase in fly ash content for reinforcement. So Aluminium- fly ash Metal matrix composites can be utilized in applications where weight reductions are required.

2. Tensile strength, impact strength and hardness were determined for the samples fabricated. Increasing fly ash content upto 15% resulted in increase in the tensile strength of the Al. Similarly hardness of the composites were also found to increase with increased fly ash content.

The properties of the best specimen 3 was used for modelling an UAV wing and the analysis results are compared with the model using AL 7075 properties and it is observed that the deformation on the composite aircraft wing is less than that of Al 7075 wing. More over Fly Ash is a waste product from thermal power plant and it can be used as a composition in metal matrix composite and also it is a cost worthy product. Hence Aluminium – flyash metal matrix composite can be used as a low cost, high strength, light weight material for application to aircraft structures and wings.

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