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Comparative Study on Aerospace Conventional Engineering Material and Glass Fiber Reinforced Polymer - An Experimental Approach

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Abstract

An increase in the application spectrum of composite materials necessitates cost effective high quality rapid processing in order to meet stringent design as well as market requirements. Material selection has become one of the major problems in aviation. The objective of the current study is to compare the bending strength of Glass Fiber Reinforced Polymer (GFRP) with the conventional material of aviation industry (ie., aluminium). The deflection test was performed on standard bending test equipment by applying the concentrated loads on the cantilever specimens, which were made of Glass Fiber Reinforced Polymer fabricated by hand layup technique and the Aluminium specimen was made and supplied with the test equipment. On performing the bending test it is observed that aluminium shows promising results where high modulus of elasticity is considered and the GFRP is found to be the cheap and best material where lower weight is considered and young's modulus of material is of low importance.

Keywords: Deflection; Young's modulus; GFRP; Concentrated load.

1. INTRODUCTION

Composites are used because of their adaptability to different situations to serve specific purposes and exhibit desirable properties. Due to low cost glass fiber became the natural option where high elastic modulus is of less importance [1]. Competing requirements for weight are foremost in the mind of the designer and surprising levels of progress have been made in extreme environmental structures.

In real practice the wings of an aircraft are subjected to different loadings especially the Lift distribution, engine & structure weight, and fuel weight. Both the Lift and engine/structure weight act opposite to each other which causes the wing to bend in downward direction at the root and upward at the tip of the wing. So, the selection of a good material entails us to have a better knowledge of bending or deflection properties of material which it has to sustain [2]. The evolution of deflection in bending tests is a function of number of cycles of load and can be expressed as the relative reduction in elastic modulus [3]. The bending fatigue tests were carried out using different orientations of the glass fiber impregnated in the epoxy resin to understand the behaviour of the material [4]. The tensile behaviour of the GFRP subjected to different environmental conditions was investigated and the degradation of the material was observed [5]. The present paper focuses on the deflection suffered by the prepreg obtained by impregnating the glass fiber in isopthalic resin which is a polymer resin. The deflection suffered by aluminium specimen is also calculated and compared with that of the prepreg in order to know the better material that can be used so that the bending effect on airplane is minimal.

2. Experimental setup:

2.1: Preparation of Specimen:

A rectangular specimen was prepared by the hand layup technique. To prepare the specimen, a mould with dimensions 601x51x15mm was made using sheet metal. The mould is shown here in figure 1.

Figure 1: Mould

Once the moulds are prepared the next task is to prepare the specimen using the fiber and matrix material. The matrix is prepared by mixing 10% catalyst (Methyl Ethyl Ketone Peroxide) and 2% accelerator (Cobalt) by weight in Isopthalic resin (IS-4011) [6]. A fine coat of Gel (CRG5-56) is applied in the inner walls of the moulds. The composite material is obtained by combining the matrix and E-glass continuous fiber in the ratio of 5:3 by weight, where the fiber is used as reinforcement agent. After 30 minutes curing time the specimen is removed from the mould and exact dimensions were obtained by fine grinding the oversized part. The dimension of specimen for bending test used here is 600 x 50 x 13 mm. For experiment the aluminium 635116 bought from Hindalco Industries Ltd is used. Both aluminium and composite specimens are shown below in figure 2.

Figure 2: Specimens of Aluminium & GFRP

2.2: Test Procedure:

Initially the weights of both aluminium and GFRP specimens are taken so as to compare both materials and then the deflection test is carried out. For given same dimensions the weight of the aluminium specimen is found to be 1.37 kg's and that of GFRP specimen is found to be 0.595 kg's.

The deflection test was carried out by clamping one end of the specimen and the other end held free. The deflection test arrangement for both aluminium and composite cantilever beam is shown in figure 3. The test was performed using both aluminium and composite specimens by applying concentrated loads at the free end. The obtained deflection reading is noted and young's modulus of the material was calculated by using the formula $E = (Wl^3)/3\delta I$ [7].

Where E – Young's modulus

W – Load applied

l – Length of the specimen

δ – Deflection
I – Moment of inertia

The moment of inertia is obtained by

$I=bd^3/12$

Where b – breadth of the specimen
d – depth of the specimen

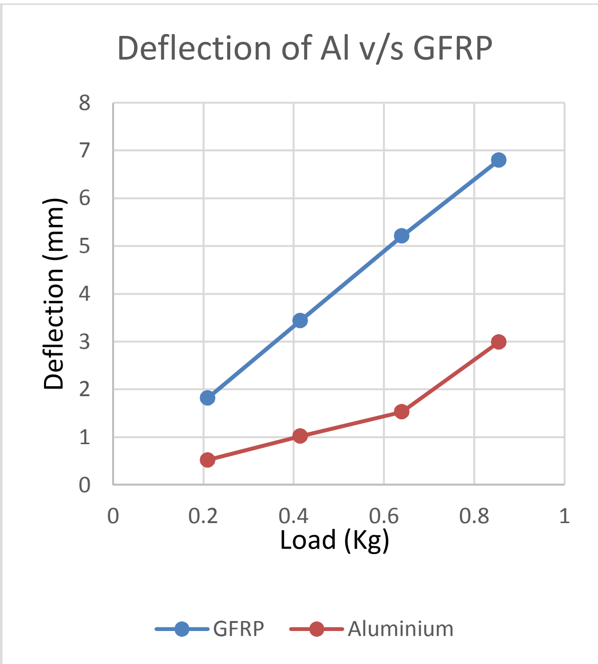
Figure 3: Deflection test arrangement

3. Results & discussion:

By applying the above formula it is observed that the young's modulus of the GFRP composite is 9.39 GPa where as aluminium has 28.7 GPa. Different graphs are drawn to compare the conventional aluminium with the GFRP composite.

From the deflection graph it is observed that the deflection suffered by the Aluminium specimen in very low when compared to that of a composite specimen. It is also observed that the specimen shows a deflected value even after removing all loads. This means that once the material is subjected to bending it loses its static equilibrium and attains a neutral position.

A graph is shown for the deflection of beams with the varying loads (Graph 1).



Graph 1: Load v/s Deflection

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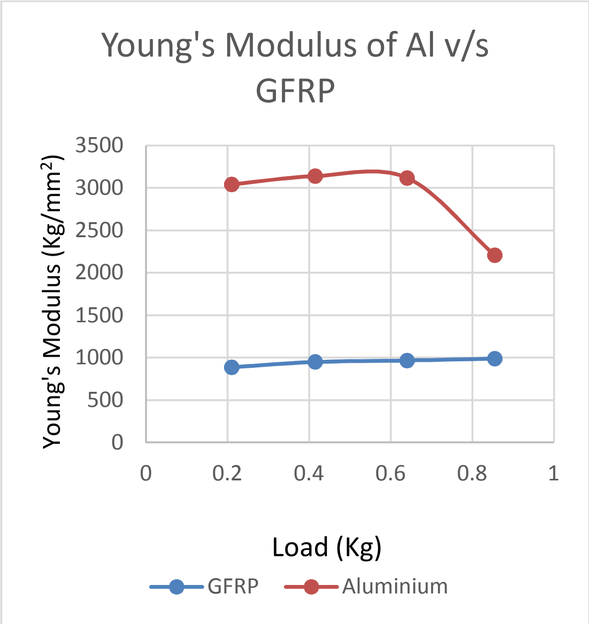
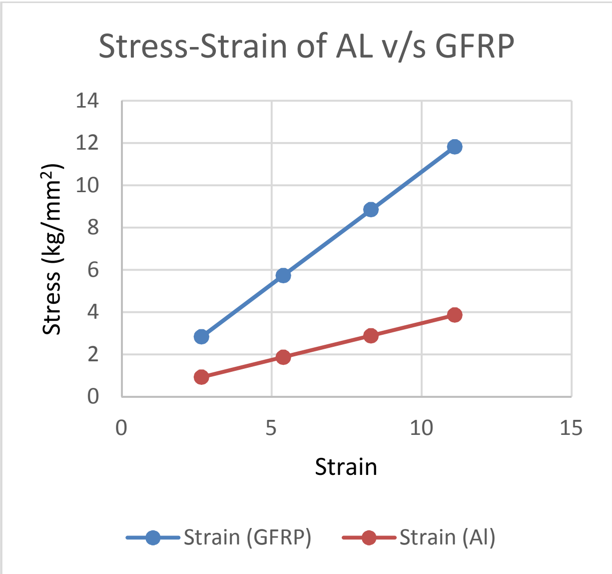
The following graph compares the young's modulus of both aluminium and GFRP composite (Graph 2).



Graph 2: Load v/s Young's Modulus

The young's modulus graph shows that with an increase in load the young's modulus of the Aluminium specimen increases initially and then decreased gradually. But the young's modulus of the GFRP is increased with increase in load. On comparing both materials aluminium can be preferred where elastic modulus is of greater concern.

A graph indicating the stress-strain readings of both aluminium and GFRP is shown below (Graph 3).



Graph 3: Stress – Strain

For an applied stress the value of strain for Aluminium is observed to be lower than the GFRP composite material. which makes it to withstand loads without much change in its structure. GFRP due to its elastic nature undergoes more deflection which makes it unsuitable material for entire wing structure.

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Conclusion:

From the comparative investigation it is observed that there is a makeable reduction in young's modulus of GFRP composite than the aluminium. Based on the result obtained the following conclusions can be drawn:

1. Aluminium shows better performance in deflection, strain, and young's modulus when compared to the GFRP specimen.
2. With the same cross sectional area due to lower weight the GFRP shows least feasible properties than aluminium.
3. The advantage with the composites is weight reduction i.e., Almost half of the weight is reduced by using the GFRP, but this can be applied only to internal or external structural components where the effect of load is less.

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