International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 03, March-2015

Free Vibration Studies on Bi-Directional Composite Beam

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***Abstract*— Composite materials are made from two or more constituent materials with significantly different physical or chemical properties, that when combined, produce a material with entirely different characteristics. They are exceptionally strong and light compared to traditional materials. Bi-directional composite beam of rectangular cross section was fabricated using bi-directional glass fibers and epoxy resin. It was then subjected to free vibration analysis considering the beam as cantilever with fixed free boundary condition. The natural frequencies of the beam corresponding to different modes were estimated using a vibration measuring apparatus integrated with software. Along with the experimental analysis, modal analysis was also conducted on the beam using ANSYS commercial finite element software. The results of both the analyses were compared and were found to be in good agreement.**

***Keywords* - Bi-*directional composite beam, Free vibration, Glass-epoxy, Compression molding, Natural frequency, Mode shape*.**

I. INTRODUCTION

Glass epoxy based fiber composite materials has got tremendous applications in building, construction and maritime industries. These applications are attributed to their high strength to weight ratio. Use of bi-directional fibers ensures uniform strength for the beam in both X and Y directions. Introducing of free or forced vibrations on the structure could seriously affect its stabilities. The frequency at which an object vibrates when it is not disturbed by an external force can be described as its natural frequency. The effect of material properties on natural frequency have been a topic of research for a long time. The present work addresses the fabrication of composite beams using bi-directional fibers and the free vibration studies on the beam. For vibration analysis the beam is taken to be a cantilever with fixed free boundary conditions [1]. The analysis is done using a free vibration apparatus integrated with software for the purpose of frequency determination. An accelerometer is placed on the beam under consideration to determine the displacement on being subjected to free vibration. The natural frequencies were found out experimentally using DEWETRON software. The natural frequencies of the structure found out experimentally were validated using commercial Finite Element software ANSYS.

II. EXPERIMENT DETAILS

2.1: Fibre Preparation

The scale available at Compression Moulding Machine was 300 mm x 300mm. The fibres were cut to the required dimensions of 300 mm x 300 mm using scissors. The fibre had a thickness of 0.5mm. The glass fibre was bi-directional glass fibre, 16 fibres were cut to the required dimensions.The resin was mixed with a hardener in the ratio 9:1 using the a resin mixing machine for large quantity of the resin. For small qunatity the resin is taken in a bowl for mixing properly[2][3].

2.2: Compression Moulding

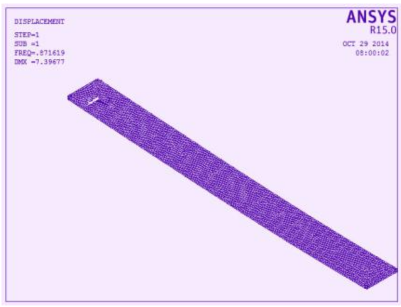
Hand lay-up method was perfomed for the laying the fibres. After completion of lay up process, manufacturing of the compsite was done by compression moulding. Compression moulding was done for the manfacturing of the composite material. The machine was cleaned properly and a mylar sheet was placed so that the resin doesn’t get bonded to the machine surface. A gel coat was provided below the mylar sheet for easy seperation. Mass of the fibre was weighed and an equal mass of resin was taken. Some extra resin was taken to compensate the loss due to heating of resin. Alternate layers of fibre and resin were placed and finally a mylar sheet was placed on top. The entire setup was compressed and pressure along with temperature was provided. A temperature of 80°C was provided for 15 minutes for curing using an electric panel. It was placed in the machine setup for about 15 hours under a pressure of 50 bar. Finally the composite plate was taken out and the dimensions of the beam were drawn on it. Later it was cut out and the sharp edges were smoothened[4][5].

III. NATURAL FREQUENCY EVALUATION OF ALUMINIUM BEAM USING ANSYS

Dimension the Aluminium beam considered for analysis is 300 mm x 30 mm x 3 mm. The analysis was done using fixed free boundary condition. The natural frequency was found out experimentally was validated and modeled in ANSYS software [6]. The results obtained are very close which implies the methodology used is correct.

3.1: Results obtained from ANSYS Software

The Fig 1 shows the first, second and third natural frequencies along with its mode shapes obtained from ANSYS. The results obtained from ANSYS matches with the analytical expression used [7].



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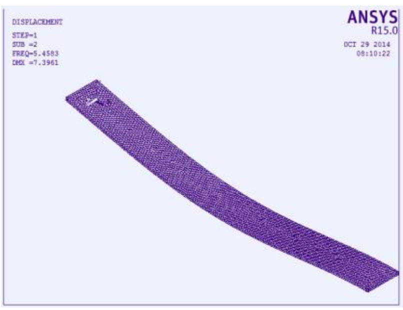

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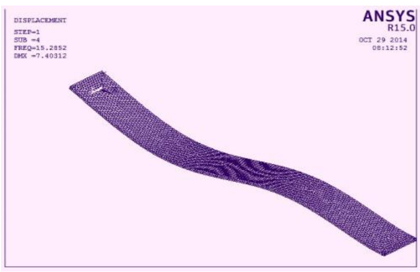


(c)

Fig 1 (a) First Mode, (b) Second Mode, (c) Third Mode of Aluminium beam

3.2: Experimental determination of Natural frequency of Aluminium beam

Free vibration analysis was conducted on the Aluminium beam. The DEWETRON software was used for the determination of natural frequency. DEWETRON is a firm established in the late 80's as a provider for components of measurement to act as building blocks for data acquisition systems. Later on they started providing software solutions too. Modal analysis is needed in every modern construction. The measurement of system parameters, called modal parameters, is essential to predict the behaviour of a structure. Parameters like resonant frequency; structural damping and mode shapes are experimentally measured and calculated using the DEWETRON software. Starting up from 8 channels, up to 1000 channels could be used for complex structures. In this experiment a 12 channel box setup was used, out of which only 3 channels were used [8].

3 .2.1: Results from experiment

Fig.2. shows the result from experiment for Aluminium beam. The natural frequencies obtained are

First mode: 0.91Hz
Second mode: 5.12Hz
Third mode: 15.34Hz

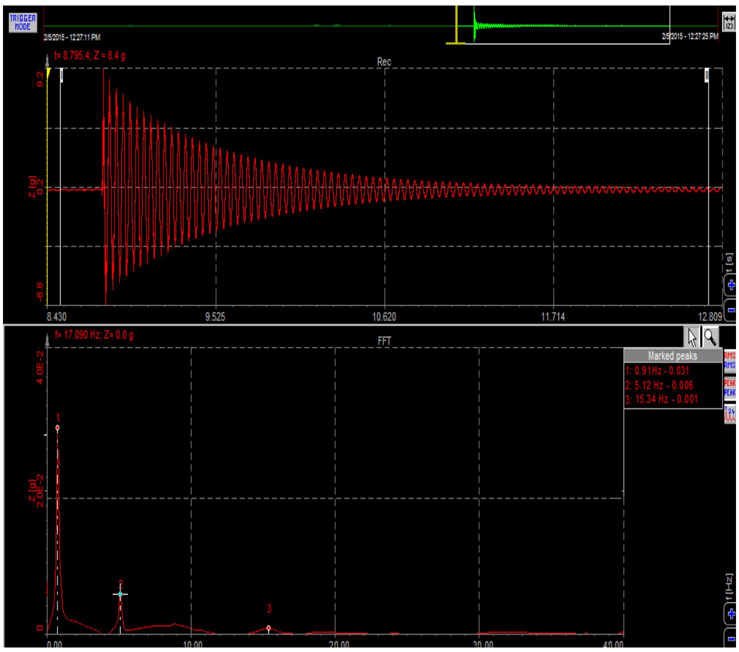


Fig 2. Result from experiment for Aluminium beam

The natural frequency of first, second and third mode is shown in Table 1.

TABLE 1: COMPARISON OF ANALYTICAL, ANSYS AND EXPERIMENTAL RESULTS.

Aluminium beam	**First mode (Hz)**	**Second mode (Hz)**	**Third mode (Hz)**
Analytical	0.8638	5.414	15.16
ANSYS	0.8716	5.4583	15.2852
Experimental	0.91	5.12	15.34

IV. RESULTS AND DISCUSSIONS FOR COMPOSITE BEAM

4.1 Burn-out Test

To find the percentage of of resin and fibre in the manufactured component a volume fraction test was conducted. The total weight of the composite was measured using a weiging balance of least count 0.0001 grams. The composite was later placed in a furnace shown in Fig .3at a temperature of more than 600^0C and placed inside the furnace for 10-15 minutes. The resin got burned and the remaining fibre only remained. The weight of the fibre was measured again. By taking ratio, the volume fraction was found out.

Fibre weight in test sample = 14.1396 gram
Resin weight in test sample = 11.039 gram
FVF - Fibre volume fraction = 0.376
FWF - Fibre weight fraction = 0.56157

Fig 3. Burn out test using furnace

4.2 Determination of Youngs Modulus using UTM.

The composite structure manufactured was tested under the Universal Testing Machine (UTM) for determining its strength in X and Y direction. The result obtained from the computer connected to the universal testing machine is provided in the Fig 4 below.

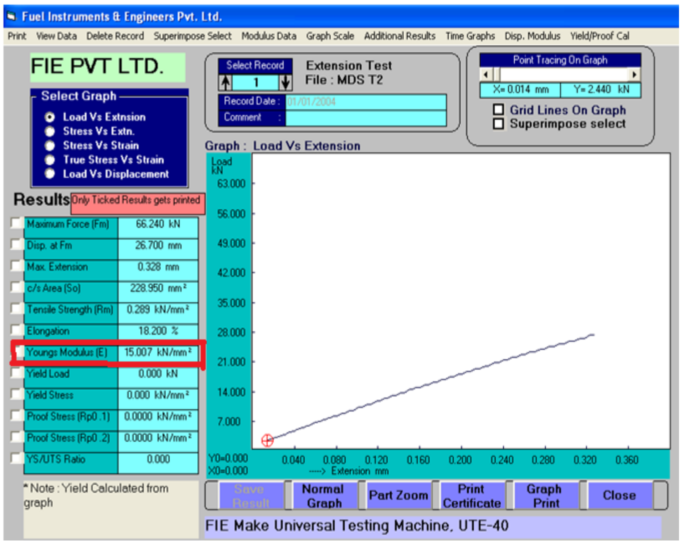
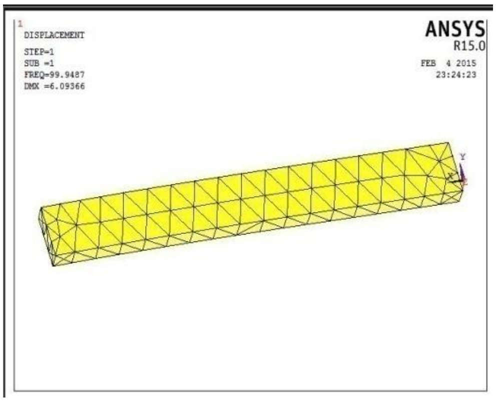


Fig 4: Results from UTM.

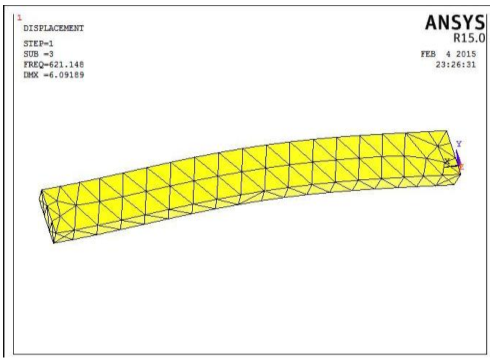
Youngs modulus in X direction Ex = 15.007 KN/mm^2
Youngs modulus in Y direction Ey = 15.055 KN/mm^2

4.3 Natural frequency evaluation of Composite Beam using ANSYS

The natural frequency of the composite beam was found out using ANSYS software and experimentally. The beam dimension used for the analysis was 214 mm x 27 mm x 10 mm. The density of the material was found to be 1860kg/m^3 The first, second and third modes obtained were shown in Fig 5.



(a)



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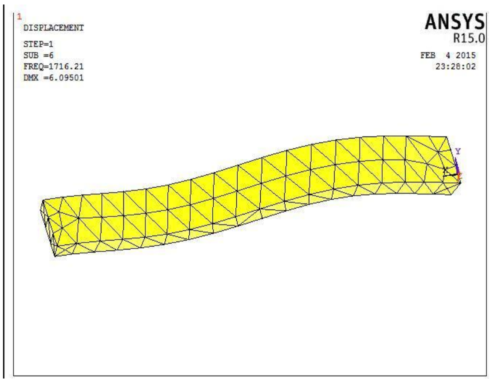

(c)

Fig 5: (a) First Mode, (b) Second Mode, (c) Third Mode

4.4 Experimental Determination of Natural Frequency of Composite Beam

The natural frequency of the composite beam was found using Cantilever beam test using the apparatus shown in Fig 6.

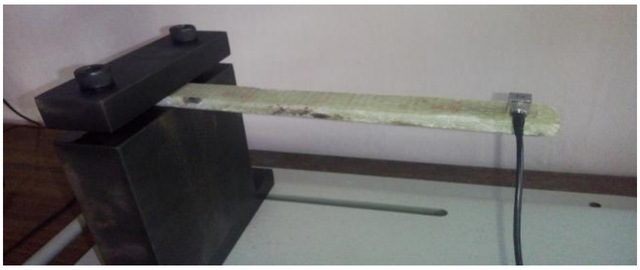

Fig 6. Cantilever Beam Test set up

The experimentally obtained results are shown in the Fig 7. Natural frequencies obtained experimentally and using ANSYS software are shown in Table 2. The values are in good agreement.

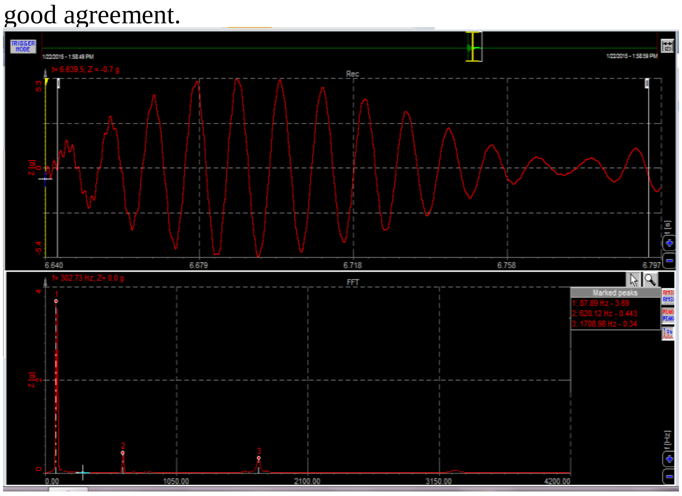

Fig 7: Result from experiment

TABLE 2: COMPARISON OF EXPERIMENTAL AND ANSYS RESULTS

Composite Beam	**First mode**	**Second mode**	**Third mode**
Experimental	87.78Hz	620.12Hz	1708.96Hz
ANSYS	99.921Hz	621.74Hz	1716.21Hz

V. CONCLUSION

Bi-directional glass epoxy composite beam was manufactured and its properties were determined. Free vibration analysis of composite beam was done both experimentally and using ANSYS software. Initially the methodology was proven using an aluminium beam. Neglecting minor experimental errors, the values were found to be in good agreement.

VI. REFERENCE

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