Experimental Investigation on Vibration Characteristics of Jute Fiber Reinforced Composite Material

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Abstract— This work presents the vibrational characteristics of composite material that is formed by a jute fiber reinforced epoxy matrix composite. An experimental model analysis was conducted on the composite material with cantilever beam structure to get the natural frequency, damping and mode shape. The experimental work is disbursed completely different for various layers of configuration by exciting the composite beam with different excitation frequencies by software model read package. The obtained mode shape reveals the deformation pattern of the structure like its natural frequency. Additionally the finite element modeling and analysis was disbursed by using ANSYS workbench for finding the natural frequencies and mode shapes of the finite element model of jute fiber reinforced epoxy matrix composite. Finally the finite part model of jute fiber reinforced epoxy matrix composite is valid with the obtained experimental results.

Key words: Jute wove composite, Frequency Response function, Modal Analysis, Finite element Method

I. INTRODUCTION

Woven fabrics as an attractive reinforcement provide wonderful integrity and conformability for advanced structural composite applications. The reinforcement of composites with industry driven woven fiber materials because improved properties of composite structures in terms of acoustical, elastically and thermal properties. Jute fibers are the foremost usually used ones in low to medium performance natural composites attributable to their high tensile strength and low cost. In woven fiber composites, fibers are woven in each principal directions at right angles to every different (warp and fill directions). To better perceive any structural vibration drawback, the resonant frequencies of a structure need to be known and quantified. Now days due to the advancement in laptop motor-assisted knowledge acquisition systems and instrumentation, experimental modal Analysis has become an especially important tool within the hands of an experimentalist. A number of researchers are developed varied resolution ways to analysis the dynamic behavior of laminated composite laminates. but experimental investigations on woven material composite laminated Structures are still restricted. There are few experimental investigations of the free vibration of free-free orthotropic plates.

Clary [1] investigated on paper and through an experiment the impact of the impact of fiber orientation on the primary 5 flexural modes of rectangular, unidirectional, boron-epoxy panels. The agreement between theoretical and experimental frequencies was typically smart, although there have been massive errors in a number of the predictions of thinner panels.

Cawley and Adams [2] used finite part methodology including transverse shear deformation to predict the natural modes of free-free CFRP plates. This methodology created improved accuracy for the theoretical results for orthotropic plates.

Dutt and Shivanand [3] studied the free vibration response of CF- F-F and C-F-C-F woven carbon composite laminates employing a FFT analyzer and compared with FEM tool ANSYS. This work presents an experimental study of modal testing of woven fiber jute/Epoxy laminated composite plates victimization FFT analyzer. The most objective of this work is to contribute for a better understanding of the dynamic behavior of elements made of industry driven woven fiber composite materials, specifically for the case of plates. The results of various geometrical parameters as well as range of layers, aspect ratio and fiber orientation of industry driven woven fiber composite plates in free-free boundary condition are studied in details.

II. EXPERIMENTAL PROGRAMME

A. *Materials Required for Fabrication of Plates*

The constituent materials used for fabricating the epoxy/jute fiber plates are: jute woven roving as reinforcement (from Owens corning), Epoxy as organic compound, Hardener as catalyst (10% of the weight of epoxy), Polyvinyl alcohol as a releasing agent.

B. *Fabrication Procedure*

The composite plate specimens used in this analysis were made of 0/90 woven jute fiber with epoxy matrix. Specimens were fabricated by hand lay-up technique. The percentage of fiber and matrix has taken as 50:50 in weight for fabrication of the plates. A flat laminate rigid platform is chosen. A plastic sheet i.e. a mould releasing sheet was unbroken on the laminate platform and a thin film of polyvinyl alcohol is applied as a releasing agent by use of spray gun. Laminating Starts with the applying of a gel coat (epoxy and hardener) deposited on the mould by brush, whose main purpose was to supply a swish external surface and to protect the fibers from direct exposure to the surroundings. Ply was cut from roll of woven roving. Layers of reinforcement were placed on the mould at top of the gel coat and gel coat was applied once more by brush. Any air which can be entrapped was removed using steel rollers. If the method of hand lay-up was the continuation of the higher than process before the gel coat had totally hardened. Once completion of all layer, again a plastic sheet was lined the highest of last ply by applying polyvinyl alcohol within the sheet as releasing agent. Again one flat ply board and a significant flat metal rigid platform were kept prime of the plate for pressing purpose. The plates were left for a minimum of 48 hours in temperature before being transported and move exact form for testing.

C. Determination of Material constants

The material constants of woven fiber jute/Epoxy composite plate were determined through an experiment by acting tensile tests on specimens cut in longitudinal and transverse directions, and at 45° to the longitudinal direction using INSTRON 1195 machine as per ASTM standard: D 3039/D 3039M- 2008[5]. The shear modulus was determined using the formula from Jones [6].

Plate no	Lay-up	N	E_1 (Gpa)	E_2 (Gpa)	G_{12} (Gpa)	γ_{12}	ρ (kg/m^3)
1	WR	3	9.08	4.3	2.5	.25	1189
2	WR	5	13.3	5.0	3.4	.26	1262

Table 1: Material Properties of Composite Plates

1) WR: - Woven Roving
2) N: - Number of layers
3) E_1, E_2:- Elastic modulus in longitudinal direction and transverse direction
4) G_{12}:- In-plane shear modulus
5) γ_{12}:- Poisson's ratio
6) ρ: - Density

D. Experimental Setup and Test Procedure for Free Vibration Test

The connections of FFT analyzer, laptop, transducers, modal hammer, and cables to the system were done as per the guidance manual shown in fig.1. The pulse model view -12 software key was inserted to the port of portable computer. The plate was excited during a designated purpose by suggests that of Impact hammer (Model 2302-5), ideally at the fastened finish. The input signal captured by a force transducer, fastened on the hammer. The resulting vibrations of the plate selected point are measured by an accelerometer (B&K, kind 4507) was mounted on the plate to the free end by means of bees wax.

Fig. 1: Transducer used for excitation (left) and response measurement (right).

The signal was then subsequently input to the second channel of the analyzer, wherever its frequency spectrum was subsequently obtained. The response purpose was kept fastened at a selected purpose and also the location of excitation was varied throughout the plate.

III. FINITE ELEMENT METHOD

The first order shear deformation theory is used to develop a finite element approach for the prediction of natural frequencies and modes of laminated composite pates. The formulation is basically the same as that of chakra borty et al. [4]. consider a laminate composite plate of length 'a' and breadth 'b' consisting of N range of thin solid arbitrarily orienting orthotropic layers having a complete thickness 'h' is taken into account as shown in figure.2. In the present investigation, an eight noded 2 dimensional quadratic isoparametric part having 5 degrees of freedom (u, v, w, θx, and θy) per node is used for analysis. A vibration analysis of Laminated Composite plate is developed using the formulation supported finite element methodology (FEM) for fixed-free boundary conditions.

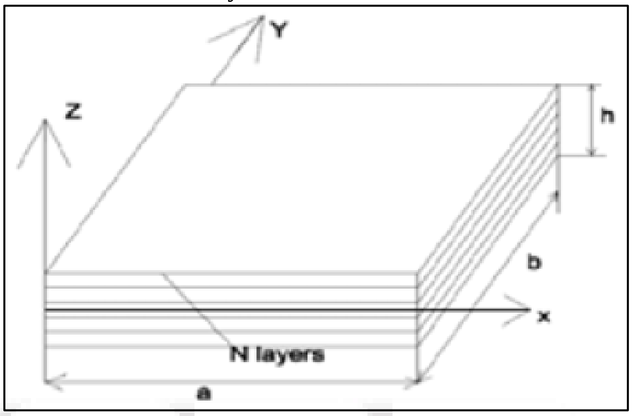

Fig. 2: Laminated Composite Plate

IV. RESULTS AND DISCUSSIONS

Numerical results are carried out to work out the capability of this formulation to predict the natural frequency of woven fiber composite plates.

A. Comparison with Previous Studies

The present formulation is valid for vibration analysis of composites panels in free-free boundary conditions as shown in Table 2. The four lowest non dimensional frequencies obtained by this finite part are compared with numerical solution published by Ju et al. [7].

Reference	Natural frequencies at free-free boundary conditions			
	1	2	3	4
Ju *et* al.[6]	73.30	202.59	243.37	264.90
Present FEM	72.53	201.39	243.54	263.26

Table 2: Comparison of natural frequencies (Hz) of vibration of 8 layer laminated composite plate [0°/90°/45°/90°]s at fixed-free boundary conditions.

a=b=0.25m, t=0.00212m, E1 = 132 Gpa, E2 = 5.35 Gpa ,G12 = 2.79 Gpa, ν12=0.3, ρ=1446.20 kg/m 3

B. Experimental and Numerical Results

After validating the formulation with the existing literature, each the experimental and numerical results for vibration study of laminated composite plates are presented. Here for free vibration analysis, the study is aimed upon the subsequent parameters:

1) *Effect of Number of layers of laminate*

To examine the effects of no of layers of laminate, 3 different types of laminate are fabricated, that are created up of three and five layers. The natural frequencies for free vibration are obtained each experimentally and numerically for fixed-free boundary condition. The variations of natural frequencies with increasing layer of laminate for average experimental and numerical results are shown graphically in figure-4. All the geometrical dimensions of the composite plates are same as delineated in table-3. From figure 4 it\'s determined that because the range of layers will increase, the natural frequency additionally will increase as excepted. there\'s a considerable variation within the natural frequency created of 3 and 5 layers.

No of layers	Thickness(h) (*m*)	Density(ρ) (kg/m^3)
3	0.003	1262
5	0.005	1293

Table 3: Geometrical dimensions of composite plate: The plate dimensions are a=0.0118m, b=0.15m,

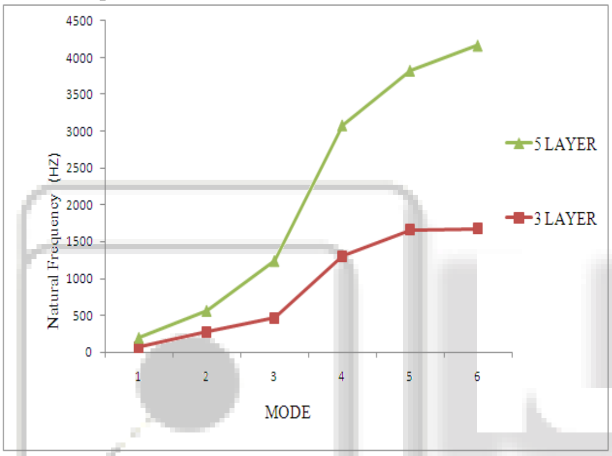

Fig. 3: Variation of natural frequency of Experimental And numerical results with different no. of layers

2) *Effect of Aspect ratio*

To study the effect of aspect ratio, 3 differing types of aspect ratios for laminated composite plates are considered i.e. for a/b value (1.0, 1.5 and 2.0).For different aspect ratios, the plate dimension varies, whereas the thickness of the plate i.e. (h=0.003m) remains unchanged. The Variations of natural frequencies of Experimental results with present FEM results of various ratio of woven JFRP under fixed-free boundary condition are shown in figure 5.

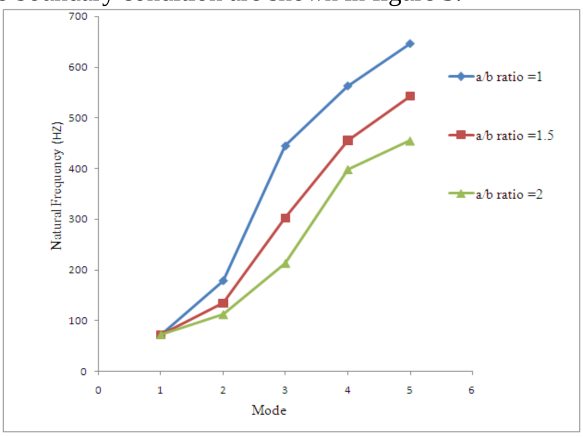

Fig. 4: Variation of natural frequency of Experimental And numerical results with different aspect ratio.

V. CONCLUSION

In the present study, both experimental and numerical study was conducted for woven roving Jute/Epoxy composite plates. The free vibration of woven jute fiber / Epoxy composite beam results are presented to show the effect of different Parameter like no. of layers in fixed-free boundary conditions. The natural frequency value difference between numerical results and experimental results are due to non uniformity in the specimens properties (Voids, variations in thickness, non uniform surface finishing) and also positioning of the accelerometers. The difference between the 3 layers and 5 layers probably due to uncertainty in elastic properties and other described reasons. This experimental method represents to predict the dynamical behavior of 3 layers woven composite, in order to design car interior door panel and other high performance structures.

A. *Pulse Report*

Pulse report for 3-layer Woven Fiber jute/Epoxy Cantilever Composite Plate

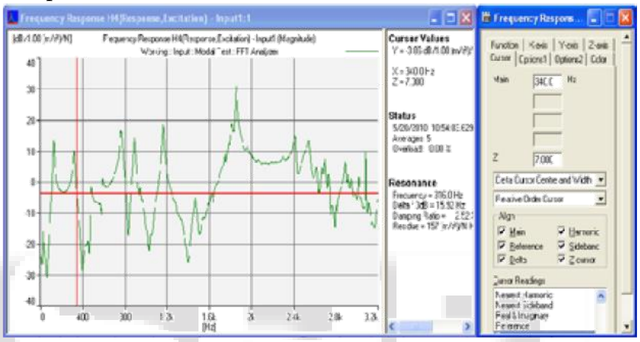

Fig. 5: Typical FRF of test specimen.

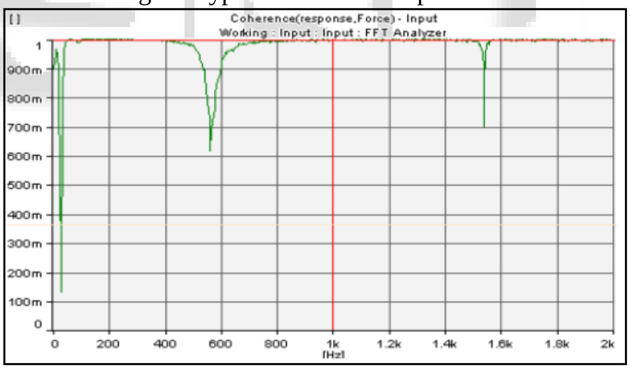

Fig. 6: Typical coherence of test specimen.

B. *Nomenclature*

a, b, h -Plate dimensions along x, y and z axes Respectively

E_1 , E_2 -Young's module of a lamina along and across the fibers, respectively

G_{12} -Shear module of a lamina with respect to 1 and 2 axis

ν_{12} -Poisson's ratios

ρ -Mass density

ω_n -Natural frequency

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