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EFFECT OF COMPOSITE PARAMETERS ON THE NATURAL FREQUENCY OF BIAXIAL JUTE FIBER REINFORCED LAMINATED COMPOSITES

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ABSTRACT

This work contributes for a better understanding of the dynamic behaviour of components made from biaxial jute fiber reinforced composite laminates by performing numerical analysis via finite element analysis, which basically yields their free vibration response. A variety of parametric studies were carried out to see the effects of various changes in the laminate parameters like orientation of fiber, stacking sequence and number of layers of fiber on the natural frequencies. Modal analysis was performed in order to determine the natural frequencies and mode shapes, which are important parameters in the design of a structure for dynamic loading conditions. The finite element simulation in this case was performed by a commercially available software package ANSYS 15.

Keywords: natural frequency; biaxial; stacking sequence; orientation angle; number of layers

INTRODUCTION

Laminated composites are typically made of different orthotropic layers, each oriented at a specific angle bonded together. Laminated composites present inherent anisotropy which allows the designer to tailor the material in order to achieve the desired performance requirements. That is, controllability of the structural properties by changing the fiber orientation angles, the number of plies and their stacking sequence.

Nowadays, jute fiber mat is an interesting option as reinforcement in the composite technology owing to the fact that natural fiber reinforced composites with thermoplastic matrices have successfully proven their high qualities in various engineering applications. It exhibits desirable properties such as bio degradability, renewability, combustibility, lower durability, excellent mechanical properties, low density and low price. They also exhibit excellent price-performance ratio at low weight in combination with the ecofriendly character which is very important for acceptance of any fiber in engineering markets.

In order to achieve the perfect combination of material properties and service performance, the dynamic behavior is a crucial point to be considered. Thus, for any structure, its natural frequency must be determined in order to ensure that the loading frequency imposed on it and the natural frequency differs considerably in order to avoid resonance. Compared to the analytical and

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experimental methods to predict changes in the natural frequencies, finite element method would be more fruitful to determine the vibration characteristics of laminated composites.

LITERATURE REVIEW

Immense research was performed pertaining to the vibration analysis of laminate composites concluding that they can be tailored to meet the particular dynamic requirements by altering different parameters such as stacking sequence of lay-up, fiber orientations and the number of fiber layers.

A three-dimensional finite element modelling was employed in [3] to simulate the dynamic response of composite laminated plates in order to extract their natural frequencies. Extensive experimental work was done to investigate the free vibration of woven fiber Glass/Epoxy composite laminate plates in simply supported boundary conditions which validated the results obtained from the FEM numerical analysis.

The alteration in stacking sequence of the laminated composite beams has been observed to result in the change of natural frequency [1]. This proves that the changes in the stacking sequence likely allowed tailoring of the material to achieve desired natural frequencies and respective mode shapes without changing its geometry. The effects of lamination sequence on the natural frequencies of vibration and buckling strength of the hybrid panels were studied in [4] using ANSYS, which basically involved the experimental and numerical investigation on parametric study of vibration characteristics of hybrid composite panels. The effect of stacking layer sequence ([0°/45°/-45°/90°], [45°/0°/-45°/90°] and [90°/45°/-45°/0°]) on natural frequencies of glass/epoxy perforated beams for the cantilever beam condition was determined [9]. The natural frequency decreased from stacking sequence [0°/45°/-45°/90°] to [45°/0°/-45°/90°] and from [45°/0°/-45°/90°] to [90°/45°/-45°/0°]. The cantilever beam with antisymmetric stacking sequence [0°/45°/-45°/90°] exhibited maximum natural frequency in all cases.

The effect of orientation angle on the natural frequency of symmetric composite beams was studied both analytically and numerically in [2], which finally concluded that the natural frequencies vary with a variation in the orientation angle. A study [5] involving extensive experimental work to investigate the free vibration of woven fiber Glass/Epoxy composite plates in free-free boundary conditions was performed. The effects of different parameters including fiber orientation of woven fiber composite plates were studied which revealed that the natural frequency of plate increases as the ply orientation increases up to [30°/-60°] and again decreases up to [45°/-45°]. In the study [6], the effect of number of layers and orientation angle on the natural frequency and mode shape for hybrid fiber/epoxy composite laminates were investigated.

The results showed that the natural frequencies increased when the number of carbon layers increased.

The effect of boundary conditions on different modal parameters including natural frequency, mode shapes and modal damping of woven glass fiber composite laminated plates were reported in [8]. Frequency response functions like natural frequency, mode shapes and modal damping for three different boundary conditions, showed that the natural frequency of fixed-fixed glass plate is the highest. Also, the natural frequency increased with an increase in mode number or constraints.

EXPERIMENTATION

Sampling & Designation of Laminate Composites

In order to conclude the effect of the following three aspects on the vibration behavior of natural fiber reinforced composite laminates, 9 different samples were designed as shown in Table I.

i) Orientation angle (θ / 90° + θ) - 10°, 20°, 30° and 40°.
ii) Stacking sequence – symmetric, asymmetric and antisymmetric.
iii) Number of layers – 4, 6 and 8.

Table I. Tabulation of sampling for the present study

Major fiber layer orientation angle in combination with 10°	**Number of Layers in the laminated composites**		
	4	**6**	**8**
20°	Symmetric	Antisymmetric	Asymmetric
30°	Antisymmetric	Asymmetric	Symmetric
40°	Asymmetric	Symmetric	Antisymmetric

Finite Element Modeling and Analysis using ANSYS

The numerical study on modal testing of aforementioned designated woven fiber jute/GPR composite laminates was performed using ANSYS 15. The type of element used to model the composites is SOLSH190 which typically suits for layered applications such as laminated shells or sandwich constructions with a wide range of thicknesses. The element is defined by eight nodes and has three translational degrees of freedom at each node. Also, it is fully compatible with 3-D constitutive relations.

The length and breadth of the model for both the boundary conditions are taken to be 330mm and 43 mm respectively whereas, the thickness of the beam varies with the number of layers in the sample. The thickness of an individual layer is 0.1266 mm.

Material Properties

The material properties required as an input to ANSYS analysis were extracted from the standard literature and are tabulated below in Table II. The density is taken to be 0.000130.

Table II. Input material properties

Elastic modulus		**Rigidity modulus**		**Poisson's ratio**	
EX	11.75e3 MPa	GXY	2.537e3 MPa	PRXY	0.415
EY	11.75e3 MPa	GYZ	2.381e3 MPa	PRYZ	0.53
EZ	7.286e3 MPa	GXZ	2.381e3 MPa	PRXZ	0.53

RESULTS & DISCUSSIONS

The natural frequencies of the designated laminate composites for the first six modes were determined for cantilever and fixed boundary conditions and are tabulated in Table III and Table IV respectively.

Sample No.	**Natural Frequency**					
	Mode 1	**Mode 2**	**Mode 3**	**Mode 4**	**Mode 5**	**Mode 6**
1	0.06957	0.435	0.5695	0.8465	1.2179	2.39
2	0.10533	0.58079	0.65782	1.2187	1.8354	3.3152
3	0.13924	0.57714	0.8671	1.5799	2.4079	3.3039
4	0.067468	0.42209	0.56218	0.89703	1.1830	2.3238
5	0.10108	0.55616	0.6311	1.2823	1.7632	3.211
6	0.13465	0.55643	0.83837	1.6343	2.3309	3.2125
7	0.066759	0.41760	0.54942	0.90768	1.1708	2.3015
8	0.10236	0.56219	0.63918	1.2711	1.7851	3.2416
9	0.13380	0.55251	0.83366	1.6714	2.3184	3.2087

Table III. Natural frequency of first 6 mode shapes for cantilever condition

Sample No.	**Natural Frequency**					
	Mode 1	**Mode 2**	**Mode 3**	**Mode 4**	**Mode 5**	**Mode 6**
1	0.44978	1.2349	1.7723	2.4186	3.2334	3.6199
2	0.67466	1.8458	2.5383	3.2484	3.5956	5.1756
3	0.89058	2.4256	3.2746	3.2847	4.6878	6.6593
4	0.43718	1.2024	1.8706	2.3566	3.2375	3.8046
5	0.65299	1.7884	2.6681	3.2056	3.4882	5.4217
6	0.86516	2.3563	3.2074	3.3844	4.5609	6.8570
7	0.43337	1.1917	1.8911	2.3367	3.1935	3.8448
8	0.65998	1.8079	2.6467	3.2310	3.5244	5.3801
9	0.85923	2.343	3.2119	3.453	4.5361	6.9852

Table IV. Natural frequency of first 6 mode shapes when both ends are fixed

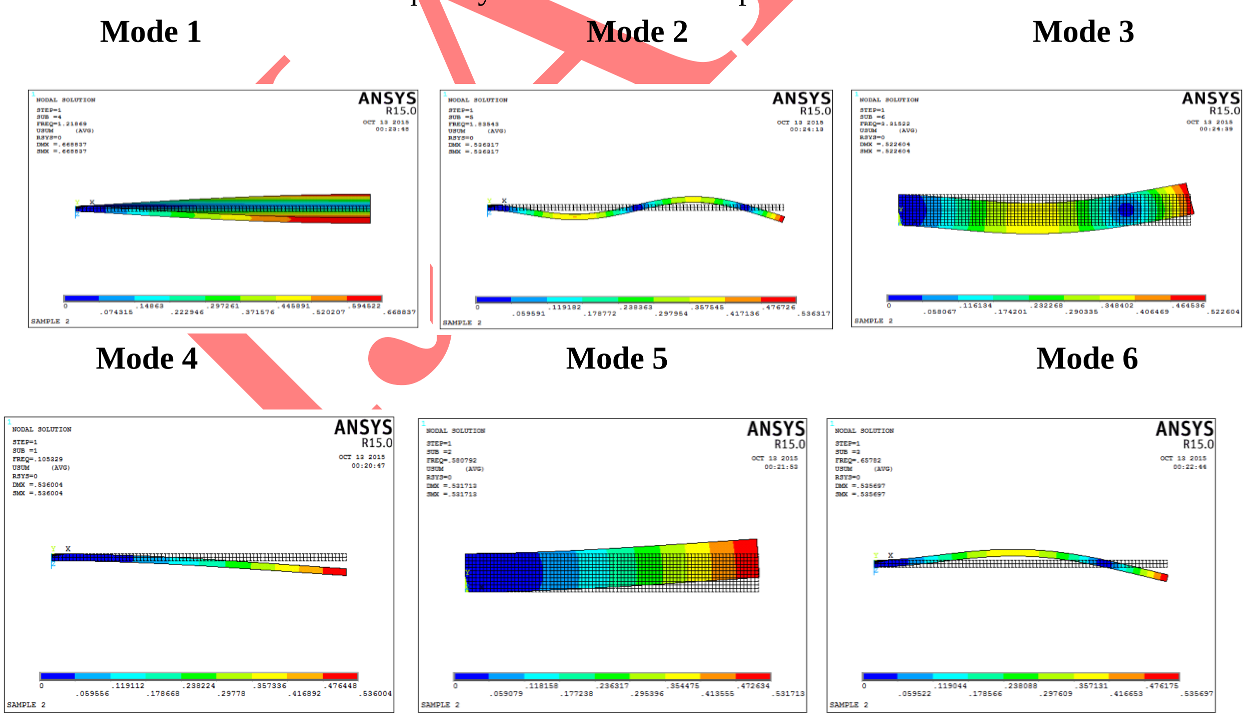
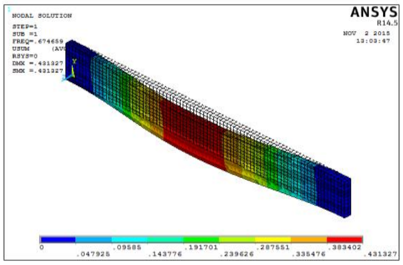
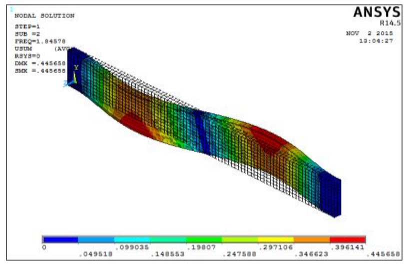


Figure 1. The first six mode shapes of the laminated composite beam ‘2’ for cantilever condition.

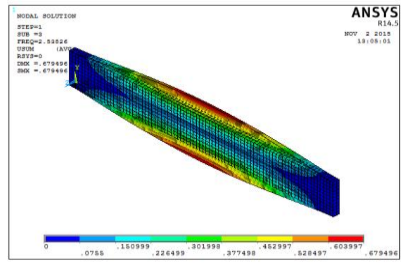
Mode 1



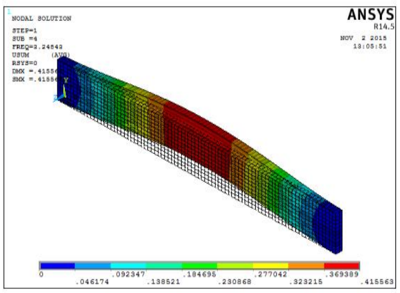
Mode 2



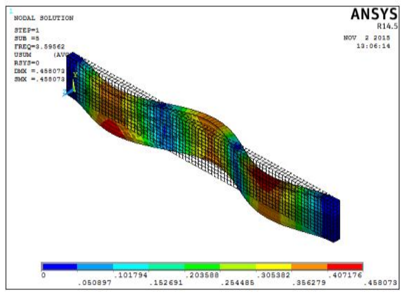
Mode 3



Mode 4



Mode 5



Mode 6

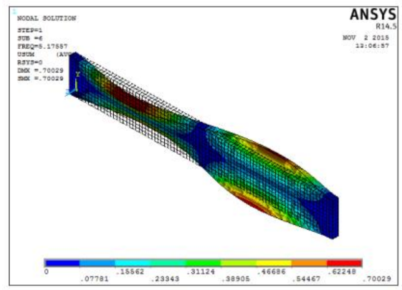


Figure 2. The first six mode shapes of the laminated composite beam '2' when the both ends are fixed.

Effect of Fiber Orientation Angle

The effect of fiber orientation on the natural frequency of the laminated composites can be witnessed from the following graphs in fig. 3 and fig. 4 for cantilever and fixed boundary conditions respectively.

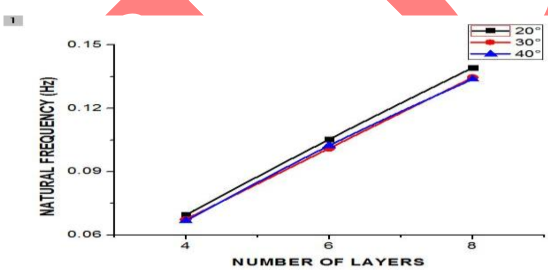


Figure 3. Cantilever condition

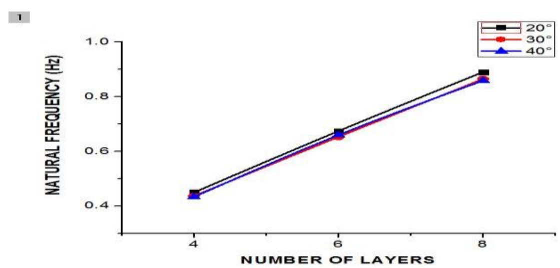


Figure 4. Both ends fixed condition

- The natural frequency increased with an increase in the number of layers in both cases.
- For each composite, the natural frequency is higher in case of cantilever boundary condition compared to the both ends fixed condition.
- Also, In each case, the natural frequency is highest for the composite with a major orientation angle of 20°

- Composites consisting of laminates oriented at both 30 and 40 exhibited almost same natural frequency, except for a slight higher value when 6 layers are present.

Effect of Stacking Sequence

The effect of different stacking sequences of laminate layers like symmetric, asymmetric and antisymmetric in the composite on its vibration properties is shown below in fig. 5 and fig. 6 for cantilever and fixed boundary conditions respectively.

Figure 5. Cantilever condition

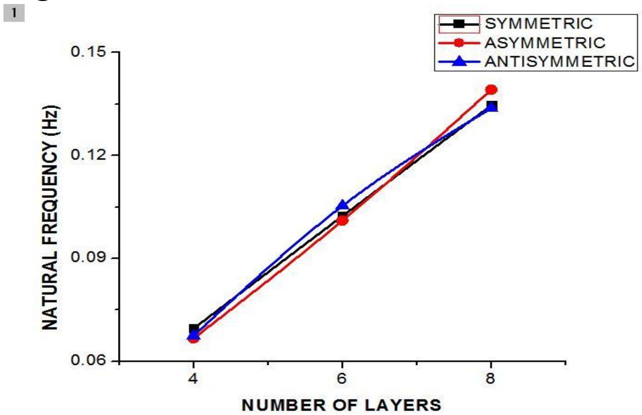
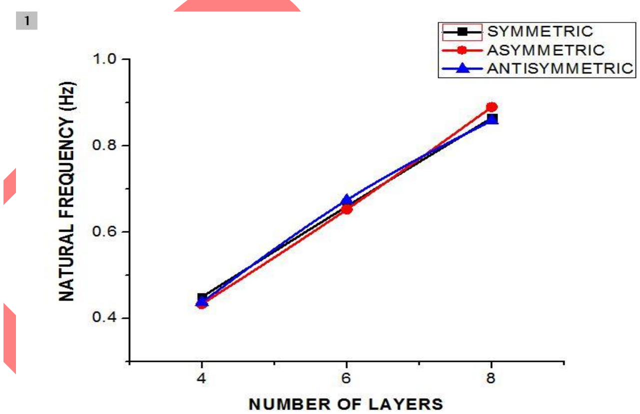


Figure 6. Both ends fixed condition



- The natural frequency of the sample with symmetry in stacking sequence increased uniformly with an increase in number of layers for both the boundary conditions.
- In composites consisting of 4 layers, all the samples exhibited almost same natural frequency.
- With an increase in the number of layers, they exhibited a significant difference, even though not in a particular order.

Effect of Number of Layers

The number of layers in the composite are varied and on analysis the effect of increasing number of layers on the natural frequency of the composite laminates is illustrated in fig. 7 and fig. 8 for cantilever and fixed boundary conditions respectively

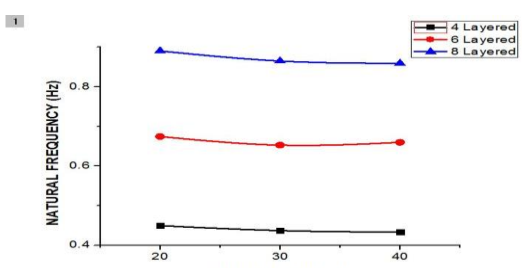


Figure 7. Cantilever condition

Figure 8. Both ends fixed condition

- In all the cases, natural frequency increased with an increase in the number of layers.
- Also, In each case, the natural frequency is highest for the composite with a major orientation angle of 20°

CONCLUDING REMARKS

- The effect of fiber orientation, stacking sequence and number of layers in natural fiber reinforced composite laminate structures were determined for cantilever condition using natural frequency shifts in ANSYS.
- Among the four layered samples with cantilever boundary condition, the composites with a major orientation angle of 20° and symmetry in stacking sequence exhibited the highest natural frequency which is 3.1% greater than [30°, antisymmetric] and 4.2% greater than [40°, asymmetric]
- The same scenario is repeated in case of four layered samples where both ends are fixed, where [20°, symmetric] exhibited 2.9% greater than [30°, antisymmetric] and 3.8% greater than [40°, asymmetric]
- Among the six layered samples with cantilever boundary condition, the composites with a major orientation angle of 20° and anti-symmetry in stacking sequence exhibited the highest natural frequency which is 4.2% greater than [30°, asymmetric] and 2.9% greater than [40°, symmetric]
- Akin scenario is repeated in case of six layered samples where both ends are fixed, where [20, antisymmetric] exhibited 3.3% greater than [30°, asymmetric] and 2.2% greater than [40°, symmetric]
- Among the eight layered samples with cantilever boundary condition, the composites with a major orientation angle of 20° and asymmetry in stacking sequence exhibited the highest natural frequency which is 3.4% greater than [30°, symmetric] and 4.06% greater than [40°, antisymmetric]
- A similar scenario is repeated in case of eight layered samples where both ends are fixed, where [20°, asymmetric] exhibited 2.9% greater than [30°, symmetric] and 3.6% greater than [40°, antisymmetric]
- In both boundary conditions, the natural frequency increases monotonically with the mode number for all types of composite panels.

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