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EFFECTS OF ANGLE PLY ORIENTATION ON DYNAMICS CHARECTERISTICS OF COMPOSITES LAMINATES

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Abstract:

The laminated composite beams are basic structural components used in a variety of engineering structures such as aero plane wings, helicopter blades and turbine blades as well as many others in the aerospace, mechanical, and civil industries. An important element in the dynamic analysis of composite beams is the computation of their natural frequencies and mode shapes. This is important because composite beam structures often operate in complex environmental conditions and are frequently exposed to a variety of dynamic excitations. In this paper, a finite element approach is used to characterize the vibration behavior of composite beam. This work has implication in the selection of composite ply orientation for better dynamic performance and the selection of laminate architectures for optimum combinations of natural frequency and mode shape with a suitable boundary condition.

Key Words: Composite Beams, Dynamic Tests, Finite Element Method & Natural Frequencies.

1. Introduction:

Fiber reinforced composites are finding increasing applications in civil engineering, transportation vehicles, aerospace, marine, aviation, and chemical industries in recent decades. This is due to their excellent features, such as high strength-to-weight and stiffness-to weight ratios, the ability of being different strengths in different directions and the nature of being tailored to satisfy the strength and stiffness requirements in practical designs. Studies on the behavior of composite beams have recently been important because of their high strength and lightweight properties on modern engineering sought in structures.

For any composite structure that may be subjected to dynamic loads, the determination of the natural frequencies is critical in the design process. It is usually the first step in a dynamic analysis since a great deal may be deduced concerning the structural behavior and integrity from knowledge of its natural frequencies. So, the researches pertain to the vibration analysis of composite beams have undergone rapid growth over the past few decades and are still growing.

2. Literature Review:

A number of researchers have been developed numerous solution methods to analysis the dynamic behavior of laminated composite beams. Khdeir and Reddy developed analytical solutions of refined beam theories to study the free vibration behavior of cross-ply rectangular beams with arbitrary boundary conditions in conjunction with the state space approach. Krishnaswamy developed dynamic equations governing the free vibration of laminated composite beams using Hamilton's principle. The effects of transverse shear and rotary inertia are included in the energy formulation. Matsunaga studied the natural frequencies of laminated beams by taking into account the complete effects of transverse shear and normal stresses and rotatory inertia. Chen et al. presented a new method of state space-based differential quadrature for free vibration of generally laminated beams. Chandrashekhara obtained the exact solutions for symmetrically laminated beams based on first order shear deformation theory including rotary inertia.

A large number of investigators address the problem of free vibration analysis of laminated composite beams. Yildirim and Kiral studied the out-of-plane free vibration problem of symmetric cross-ply laminated composite beams using the transfer matrix method. The rotary inertia and shear deformation effects are considered in the Timoshenko beam analysis based on the first-order shear deformation theory. Banerjee investigated the free vibrations of axially loaded composite Timoshenko beams using the dynamic stiffness matrix method by developing an exact dynamic stiffness matrix of composite beams taking into account the effects of an axial force, shear deformation, and rotary inertia investigated the free vibration behaviors of axially loaded laminated composite beams having arbitrary lay-up using the dynamic stiffness method taking into account the influences of axial forces, Poisson effect, axial deformation, shear deformation, and rotary inertia. Abramovich and Livshits studied the free vibration of non symmetric cross-ply laminated composite beams based on Timoshenko type equations. Eisenberger used the dynamic stiffness analysis and the first-order shear deformation theory to study the free vibration of laminated beams. Calm make study intended to analyze free and forced vibrations of non-uniform composite beams in the Laplace domain. Song and Waas studied the free vibration analyses of stepped laminated composite beams using simple higher-order theory (SHOT) which assumes a cubic distribution for the displacement field through the thickness. Yildirimused the stiffness method for the solution of the purely in-plane free vibration problem of symmetric cross-ply laminated beams with the rotary inertia, axial and transverse shear deformation effects included by the first-order shear deformation theory. Rao developed an analytical method for evaluating the natural frequencies of laminated composite and sandwich beams using higher-order mixed theory and analyzed various beams of thin and thick sections. Kant developed an analytical solution to the dynamic analysis of the laminated composite beams using a higher order refined theory. Vinson and Sierakowski obtained the exact solution of a simply supported composite beam based on the classical theory, which neglects the effects of the rotary inertia and shearing deformation.

Abramovich studied free vibration of symmetrically laminated composite beams on Timoshenko type equations .Many authors have used the finite element technique to analyze the dynamic of laminated beams. Bassiouni presented a finite element model to investigate the natural frequencies and mode shapes of the laminated composite beams. Tahani developed a new layer wise beam theory for generally laminated composite beam and compared the analytical solutions for static bending and free vibration with the three-dimensional elasticity solution of cross-ply laminates in cylindrical bending and with three-dimensional finite element analysis for angle-ply laminates. Chandrashekhara and Bangera investigated the free vibration of angle-ply composite beams by a higher-order shear deformation theory using the shear flexible finite element method. Maiti and Sinha developed a finite element method (FEM) to analyze the vibration behavior of laminated composite. Murthy, Derived a refined2-node beam element based on higher order shear deformation theory for axial-flexural-shear coupled deformation in asymmetrically stacked laminated composite beams. Ramtekkar developed a six-node

Plane-stress mixed finite element model by using Hamilton's principle. Teh and Huang presented two finite element models based on a first-order theory for the free vibration analysis of fixed free beams of general orthotropic. Nabi and Ganesan developed a general finite element based on a first-order deformation theory tostudy the free vibration characteristics of Laminated composite beams. Aydogdu International studied the vibration of cross-ply laminated beams subjected to different sets of boundary conditions. Subramanian has investigated the free vibration of laminated composite beams by using two higher order displacement based on shear deformation theories and finite elements. The main objective of this work is to contribute for a better understanding of the dynamic behavior of components made from fiber reinforced composite materials, specifically for the case of beams. In order to investigate the influence of the fiber orientation on the dynamic behavior of the components, numerical analyses using the finite element method have been carried out. The results are presented and discussed.

3. Materials and Formula:

Glass fiber was used as reinforcement in the form of unidirectional fabric and epoxy resin with catalyst addition as matrix for the composite material. The mechanical properties of the composite were calculated analytically using the simple rule of mixture more accurate values can be further obtained with some mechanical testing.

Table1 Materials properties

Materials	Properties	Symbol	Value (GPa)
E-Glass fiber	Elasticity modulus Density Poisson ratio	E_f ρ_f ν_f	76E9 2.56E9 0.22
Epoxy resin	Elasticity modulus Density Poisson ratio	E_m ρ_m ν_m	4E9 1.30E9 0.40
Laminate (orthotropic)	Elasticity modulus Density Poisson ratio Fiber volume fraction Shear modulus	E_{XX} $E_{YY}=E_{ZZ}$ ρ_c ν_{12} V_f $G_{XY}=G_{ZX}$ G_{YZ}	44.8E9 11.27E9 1780 0.28 60% 4.86E9 4.45E9

$$Vv=1-\left[\frac{\left(\frac{Wf}{\rho f}\right)+(Wc-Wf)/\rho m}{Wc/\rho c}\right] \quad (1)$$

$$\rho c=\rho f\,Vf+(1-Vf-Vv) \quad (2)$$

$$E1=Ef\,Vf+Em\,(1-Vf) \quad (3)$$

$$E2=Em\left[\frac{Ef+Em+(Ef-Em)Vf}{Ef+Em-(Ef-Em)Vf}\right] \quad (4)$$

$$\gamma 12=\gamma fVf+\gamma m(1-Vf) \quad (5)$$

$$\gamma 23=\gamma fVf+\gamma m(1-Vf)\left[\frac{1+\gamma m-\frac{\gamma 12Em}{E1}}{1-\gamma m+\frac{\gamma m\gamma 12Em}{E1}}\right] \quad (6)$$

$$G12=Gm\left[\frac{Gf+Gm+(Gf-Gm)Vf}{Gf+Gm-(Gf-Gm)Vf}\right] \quad (7)$$

$$G23=\frac{E22}{2(1+\nu 23)} \tag{8}$$

4. Modal analysis using the Finite Element Method:

Initially the beams were modeled in order to get a first estimation of the un damped natural frequencies and mode shapes. The beams were discretized using fifty finite elements typeSHELL99 using the commercial package ANSYS. This element has 8 nodes and it is constituted by layers that are designated by numbers (LN - Layer Number), increasing from the bottom to the top of the laminate; the last number quantifies the existent total number of layers in the laminate (NL - Total Number of Layers). Since each fabric layer corresponds to 2 different fiber orientations (fibers at 0° and 90°), 2 different layers were used to simulate each ply. Abstraction is made of interweaving of the fibers. This assumption does not go against the safety, since it has been proven that this interweaving has positive effects in the final composite performance when intra-ply shear effects are present Particular cases where this assumption is no longer valid would require corrections in the laminate strength data, as proposed by Tsai The material properties were then entered in the program, and the constraint imposed to simulate a cantilever beam, as shown in Fig1

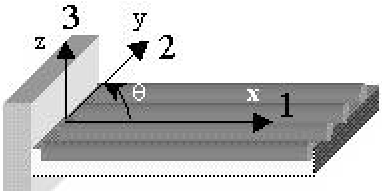
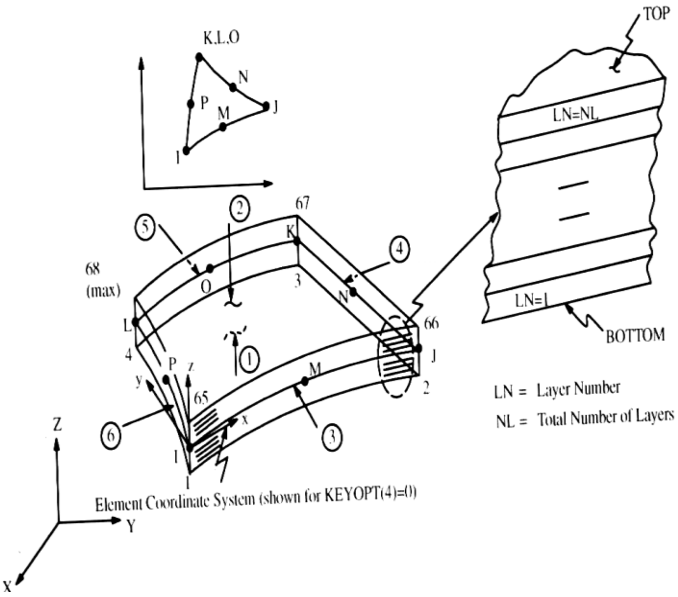


Figure 1: Cantilever Beam

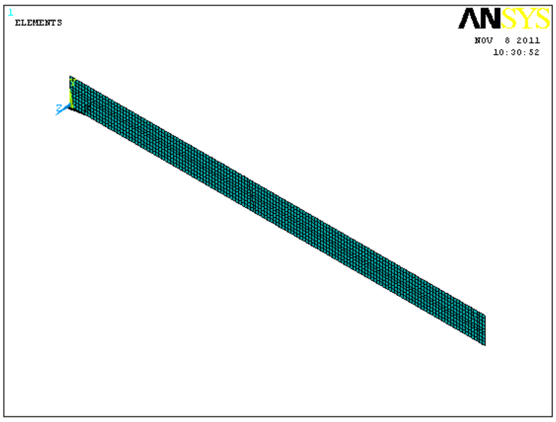


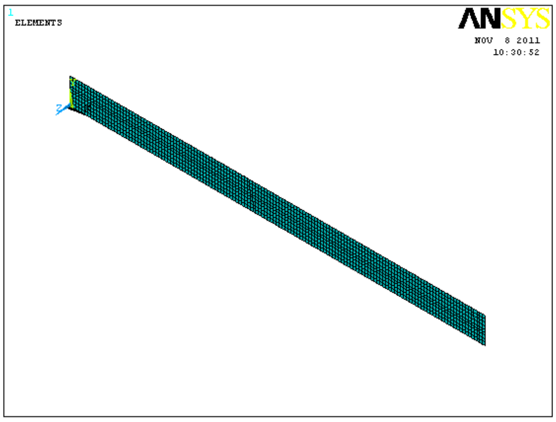
The natural frequencies of the structure to avoid resonance; The mode shapes to reinforce the most flexible points or to determine the right positions to reduce weight or to increase damping;

The damping factors With respect to these dynamic aspects, the composite materials represent an excellent possibility to design components with requirements of dynamic behavior.

5. Finite Element Modeling:

Case1: [45/-45]$_s$

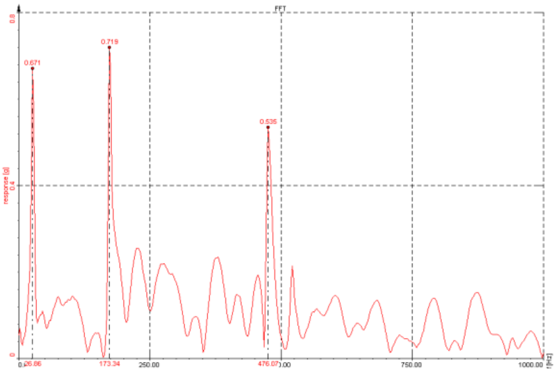




Case2: [0/90] s.

6. Experimental Results:

Case 1 (+45^{o} /-45^{o})$_s$



Case 2 (0^{o} /90^{o})$_s$

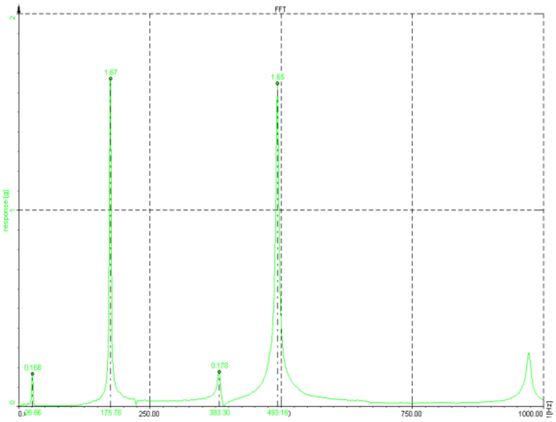


Table 2: FEA Results in both Ply Orientations

Ply Orientation	Mode Shape	FEA value (Hz)
[45/-45]$_s$	1	29.59
	2	185.16
	3	518.75
[0/90]$_s$	1	36.22
	2	204.52
	3	510.75

Table .3 Experimental Results in both Ply Orientations

Ply Orientation	Mode Shape	Experimental Value (Hz)
$[45/-45]_s$	1	26.86
	2	173.34
	3	476.07
$[0/90]_s$	1	29.29
	2	175.78
	3	493.16

The percentage of error can be calculated by using this formula

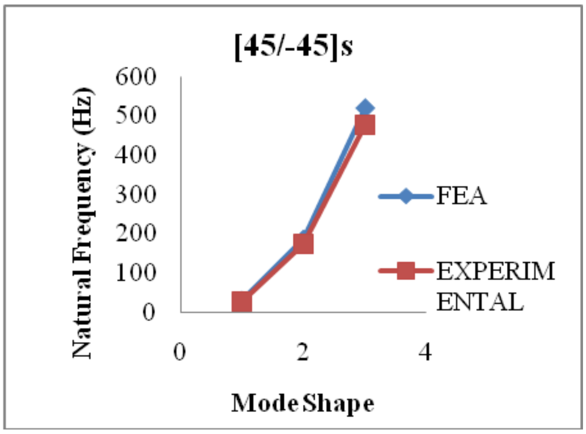
$$Percentage\ of\ Error = \left(\frac{FEA - Experimental}{FEA}\right) \times 100$$

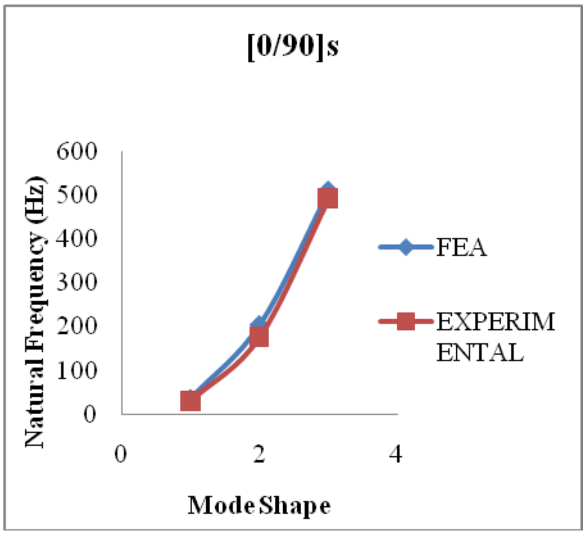
7. Comparison:

Table4 comparison of both values

Ply Orientation	Mode Shape	FEA Value	Experimental Value	Error (%)
$[45/-45]_s$	1	29.59	26.86	9.22
	2	185.16	173.34	6.38
	3	518.75	476.07	8.22
$[0/90]_s$	1	36.22	29.29	19.13
	2	204.52	175.78	14.05
	3	510.75	493.16	3.46

8. Graphical Comparison:





The graph values have shown the natural frequency vs. mode shape. The x-axis represents mode shapes and y-axis represents the natural frequency for case1 and case2

9. Results and Discussion:

The results obtained numerically for the natural frequencies and mode shapes. Figure highlights some mode shapes obtained from ANSYS (version 11) from these results it is already possible to verify the influence of the stacking sequence of the laminate the case 1, with fibers at (+45 ° /-45°) in the external layers, has in general smaller natural frequencies than the laminate of the case 2, with fibers at 0° and 90°.However, when comparing the first mode shape on torsion, the case 1 has a larger frequency than case 2. This was expected, since the natural frequencies are related to the stiffness of the structure and the case 1 (+45 ° /-45°) is much more stiffer on torsion than case 2.The opposite occurs when considering bending loads, the case 2is stiffer since 50% of the fibers are oriented at 0º, direction appropriate for bending (Flexural Modes).

Table shows experimental results as described before. The results show a good agreement with the theoretical values, proving that the stacking sequence has influence on the dynamic behavior of the structure. This was expected since from the Classical Laminate Theory (CLT), the final laminate stiffness is a result of the stacking sequence.

10. Conclusion:

In this work, the dynamic characteristics of laminated composite beams with different fiber orientations were analyzed through FE simulation. The main conclusions that can be drawn from this investigation are:

- The changes in fiber angle yield to different dynamic behavior of the component, that is, different natural frequencies for the same geometry, mass and boundary conditions.
- As the fiber angle increases, the flexural natural frequencies decrease,
- The results from ANSYS shown in general good agreement.
- The use finite element package ANSYS to investigate the dynamic characteristics of laminated composite beams, is a successful tool for such applications.
- Finally, this study helps designer in selection of the fiber orientation angle to shift the natural frequencies as desired or to control the vibration level.

From the results shown, it is clear that changes in the laminate stacking sequences yield to different dynamic behavior of the for the same geometry, mass and boundary conditions. This gives the designer one additional degree of freedom to design the laminate the possibility to change fiber orientations in order to get a more or less damped structure. This possibility makes once more these materials very attractive since it makes possible to obtain the desired. Natural frequencies and damping factors without increasing mass or changing geometry.

11. References:

1. Mohammed F.Aly I. G. M. Goda and Galal A.Hasan experimental investigation of the dynamic characteristics of laminated composite beams- international journal of mechanical and mechatronics IJMME-IJENS vol.10 no03.
2. Sourabha S Havaldar Dr. Ramesh s Sharma Swapnil jain Rahul kumar Ankit Jaiswal- effects of angle ply orientationon dynamic characteristics of composite laminates- international journal of advanced engineering and application June 2011.
3. V.Tita J.de carvalho and J.Lirani- theoretical and experimental dynamic analysis of fiber reinforced composite beams vol.25, no 3 September 2003.

4. Daniel ambrosini- free vibration of nonsymmetrical thin Walled beams numerical and experimental comparison VIII Congreso Argentino de Mecanica Computacional(2005).
5. A.krishnan and geetha George- Free vibration studies using Galerkin's finite element method vol.28 no1 19 january 1998.
6. D.J gormon accurate free vibration analysis of point supported mindlin Plates by the superposition method journal of sound and vibration (1999) 219(2) 265-277.
7. Mesut simsek and turgut kocaturk free vibration analysis of beams by using a third-ordershear deformation theory vol.32 june 2007.
8. Carlos M.tiago, vitor M.A.leita- Analysis of free vibration problems with the element-free galerkin method (2003).
9. ANSYS user manual.