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Vibrational Analysis of Composite Beams Made by Differently Oriented Layers of Epoxy Carbon

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ABSTRACT

Generally, the beams are the structural elements and cane be used in various fields of structural as well as mechanical appliances. The main performance parameter of the beam design is, it should has high strength to weight ratio. The higher strength to weight can be achieved by the help of laminated composite materials or by changing the stacking sequence on different layers of the hard fiber materials. So, it is necessary to analyze the beam under certain conditions. The beam theory is applicable to wide range of applications including blades of aviation equipments, turbine blades, etc. The main factor of the performing the dynamic analysis on composite beam is to evaluate the natural frequencies in composite beam. The present paper includes the investigation of natural frequencies of the composite beams by changing their stacking sequence.

Keywords: *Composite Beam, Fiber materials, Laminated Composite Materials, Natural Frequency, etc.*

I. INTRODUCTION

Since last decades, the different materials were used as combination to obtain the desired performance requirements of the industries. Sumerians in 4000 B.C. used straw materials to the mud for increasing the resistance of the structure as an example of composite materials. These type of combination plays vital role in the automobile industries which always tries to improve vehicle's performance by reducing the weight. Thus the technology in development of composite materials started in the recent years. The composite technology is firstly implemented in the aerospace industries (F-111 Plane). Also, Boeing 767 has made by composite materials. The evolution of high strength and stiffness with low weight of the composite materials leads attention to automobiles and industries to impose more focus on such materials. The ford motors was the first to apply the composite materials in cars and proved that the cars made by composites are lighter than the same version of steel cars. The transmission shaft was got huge reduction in weight. Recently, Chrysler designed a car model named CCV (Composite Concept Vehicle). Along with all the examples of composites, they are now a days used in domestic, medical and construction fields in order to have proper combination of materials to proper applications.

The aim of the study is to observe the dynamic behaviour of the composite materials. On that event, the fixed-fixed composite beam is considered for the natural frequency analysis with beam size of 20 mm × 6 mm × 500 mm length. The first three modes of transverse vibrations were considered for the analysis. The composite beam is made of different layers of unidirectional fibers with various combinations of orientations. The composite beam with specifications are listed in Table 1.

Table 1 the Composite Beam Specifications

Sr. No.	Beam Code	Specifications	Description
1	SS	Structural Steel	Traditional Steel Beam
2	CB01	$[0_2/30_2/0_2]_s$	Symmetric Composite Beam with two layers each of 0^0 orientation, 30^0 orientation and 0^0 orientation
3	CB02	$[0_2/45_2/0_2]_s$	Symmetric Composite Beam with two layers each of 0^0 orientation, 45^0 orientation and 0^0 orientation
4	CB03	$[0_2/60_2/0_2]_s$	Symmetric Composite Beam with two layers each of 0^0 orientation, 60^0 orientation and 0^0 orientation
5	CB04	$[0_2/90_2/0_2]_s$	Symmetric Composite Beam with two layers each of 0^0 orientation, 90^0 orientation and 0^0 orientation

II. LITERATURE REVIEW

The analysis of composite beams was performed by Maiti & Sinha [1] by considering higher order deformation theory with iso-parametric elements. They found that the natural frequency id depends on stacking sequence and various l/h ratios. As the ply angle increases and l/h ratio decreases, there is change in natural frequency.

The cross-ply laminated composite beam was observed by Jafari & Ahmadian [2]. The stiffness and mass matrices were evaluated based on energy method. The results shows that the free vibration analysis can be possible to cross-ply laminated composite materials and can be optimized under combinations of ply angles and stacking layers.

The vibration analysis of the laminated composite beam as a structure was reported by Raciti & Kapania [3] by using CLPT (Classical Laminate Plate Theory). The paper concluded that the displacements linear functions of the ordinates in the lateral direction are not much impactful for evaluating the performance of the laminated structures by the shear deformation theory.

Teboub & Hajela [4] used the symbolic computation technique to evaluate the free vibrations of simply layered composite beam by the help of first order deformation technology. The Poisson effects, bending, torsion and coupling effects were studied in the paper.

Bassiouni [5] proposed a FE model to obtain the natural frequencies and mode shapes of laminated structure. The FE model have all the laminas in the lateral displacement at a certain cross section. But there is acceptance of rotation in the lamina to lamina. The transverse shear deformations were included in the analysis.

III. MATERIALS AND METHODOLOGY

The Finite Element method had been utilized to observe the natural frequencies in a composite beam samples. The composite beam samples were made by taking different layers of Epoxy Carbon UD fibers. The required properties of the materials are tabulated in the table 2. Each sample of composite beam was created in ANSYS (Pre) with the help of symmetric two layers of the epoxy carbon UD but in different orientations. The table 1 shows the specifications of every sample of composite beams.

Initially, the ANSYS pre is utilized for the composite beams. The surface model was created by the dimensions of 500 mm in length and 20 mm in width. The model was converted into surface entity by giving the thickness as 0.5 mm. Then the model had been meshed by the standard meshing tool in ANSYS. After the meshing the pre setup was used for material data, stack up sequence, rosettes, orientations and finally the solid model was prepared by solid element. This prepared model then inserted into the modal analysis to evaluate the natural frequencies and deformations. The results had compared with the same beam made up of structural steel material and conclusion was drawn on the basis of results obtained from the modal analysis. The table 3 and table 4 shows the ANSYS results in form for total deformation at the obtained natural frequencies.

Table 2 Properties of the Beam Materials

Sr. No.	Parameters	Structural Steel	Epoxy Carbon UD
1	Density (Kg/m^3)	7850	1490
2	Young's Modulus E_1 (GPa)	200	121
3	Young's Modulus E_2 (GPa)	200	8.6
4	Shear Modulus G_{12} (GPa)	76.9	4.7
5	Major Poisson Ratio	0.3	0.27

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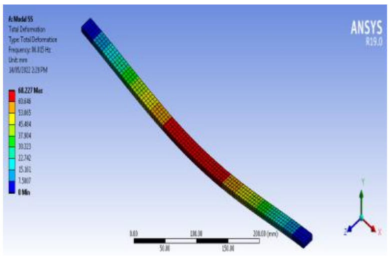
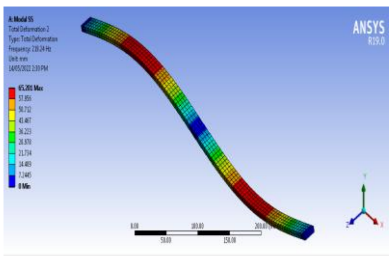
Table 3 Results of the Modal Analysis

Sr. No.	Samples	Natural Frequencies			Total Deformation		
		Mode 1 (Hz)	Mode 2 (Hz)	Mode 3 (Hz)	Mode 1 (mm)	Mode 2 (mm)	Mode 3 (mm)
1	SS01	68.23	219.24	540.94	86.82	65.20	66.68
2	CB02	62.64	173.89	344.46	168.03	160.40	161.71
3	CB03	69.65	193.28	382.82	168.47	160.71	162.08
4	CB04	82.77	227.52	444.59	168.52	160.83	161.53
5	CB05	123.77	339.17	659.82	167.81	159.4	159.79

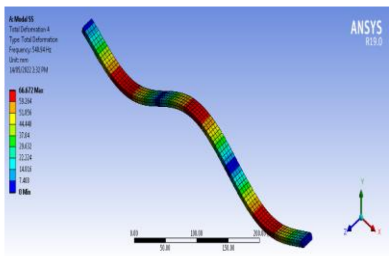
Table 4 Finite Element Analysis Results of Composite Beams



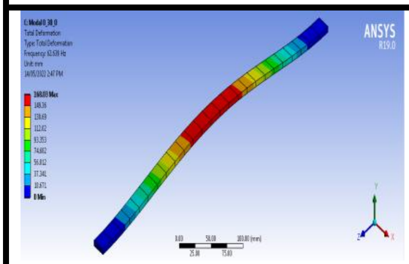
Mode 1 (SS)



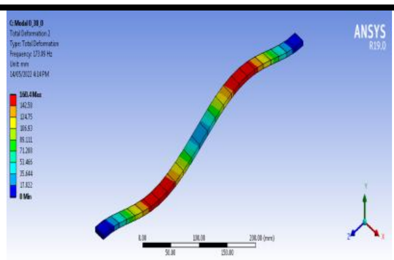
Mode 2 (SS)



Mode 3 (SS)



Mode 1 (CB01)



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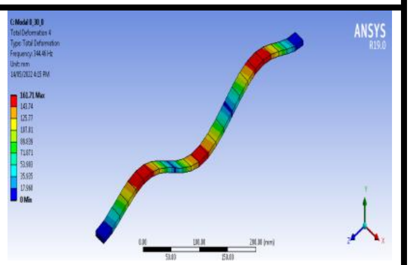

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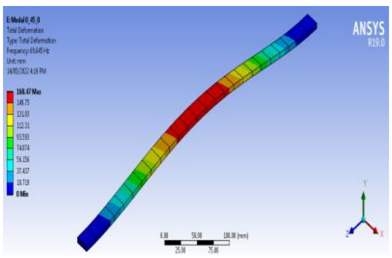
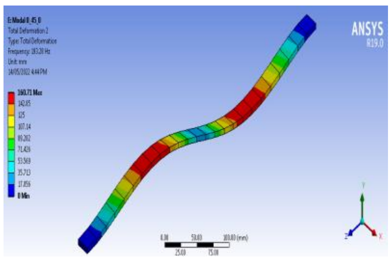
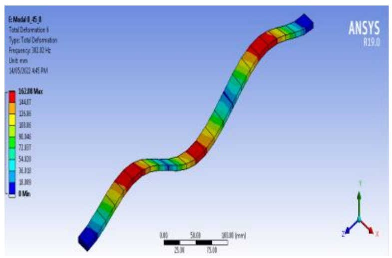


Mode 1 (CB02)



Mode 2 (CB02)



Mode 3 (CB02)

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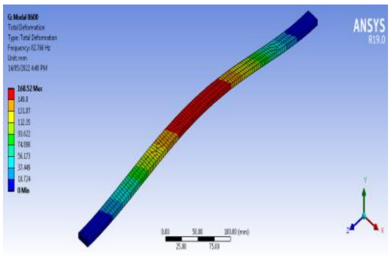
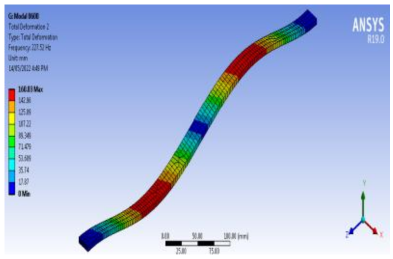
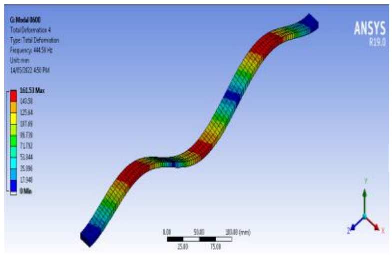
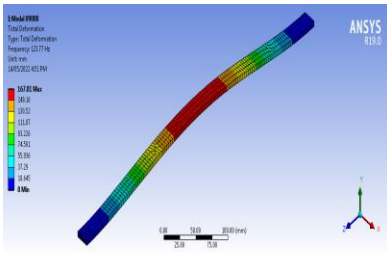
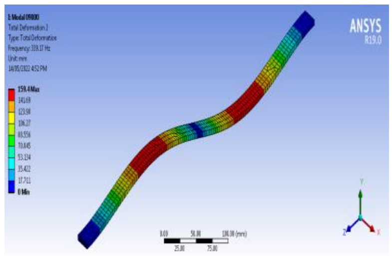
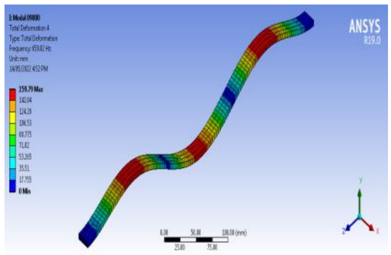
 Mode 1 (CB03)	 Mode 2 (CB03)	 Mode 3 (CB03)
 Mode 1 (CB04)	 Mode 2 (CB04)	 Mode 3 (CB04)

IV. CONCLUSION

The conclusions drawn by the vibrational analysis of composite beams made by differently oriented layers of epoxy carbon as below:

(1) The natural frequencies of the composite beams are closed to the agreement with the conventional structural steel material beam.

(2) The composite beam sample 5 gives the superficial results among all the beam samples.

(3) The specification of beam sample 5, $[0_2/90_2/0_2]_s$has good vibrating properties. Thus, it can be concluded that the to improve the natural frequency of vibrations in case of composite beams, the symmetric alternate layers of 0^0 and 90^0 orientation gives the optimum solution.

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