Eigenvalue Analysis and Rotating Condition Analysis ofComposite Box Beam

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Abstract: In general Composite elements are principal constituents of many structures and used widely in high speed machinery, aircraft and light weight structures. In many investigations there is influence of eigen frequencies, modes of vibration of structures. In this paper, a cantilever composite box beam with 0^0 and 90^0 plies is used for both Eigenvalue analysis and Rotating condition analysis. With the help of Comsol multiphysics, a structural solid mechanics tool, is used to study the Eigenvalue analysis and Rotating condition analysis of composite box beam. The analysis of beam is done at different eigenfrequency value and different angular velocity for getting different mode shapes. The displacement value of composite box beam is analysedat different rotational speed

I.INTRODUCTION:

Composite material is having their superior fatigue characteristics, greater damage tolerances, andlarger stiffness-to-weight ratios as compared with their metal counterparts. Despite these advantages, composite materials generally increase the level of uncertainties for the overall structural system. For the preliminary design of helicopter rotor blades thin walled structures such as box-beams are used.

Number of researchers have been conducted no. of experiments on composite thin-walled beams.. Chandiramani et al. [1] investigated optimal vibration control of a rotating composite beam with distributed piezoelectric sensing and actuation. Chandra and Chopra [2] investigated the vibration characteristics of rotating composite box beams by experiment and theoretical methods
Pawar and Jung., [3] investigated an active vibration reduction of hingeless composite rotor blades with dissimilarity using the active twist concept and the optimal control theory. . Numerical results has shown the impact of addressing the blade dissimilarities on hub vibrations and voltage inputs required to suppress the vibrations were demonstrated. Song and Librescu [4] studied the free vibration of anisotropic composite thin-walled beams with a closed cross-section contour using an extended Galerkin method. Chandrashekhara and Bangera [5] investigated the free vibration of angle-ply composite beams by a higher-order shear deformation theory using the shear flexible FEM Aydogdu M.,[6] obtained experimental results for obtaining the natural frequencies and mode shapes for cantilevered beam with solid cross sectionsmade out of graphite epoxy and boron epoxy composites. Hung and Chopra [7] conducted a study of the influence of ply layups on the aeroelastic stability of a composite rotor blade in hover. The structural model of the blade is taken as a closed-cell rectangular box. Stability is studied as a function of the ply layups of the sides of the box. Song et al. [8] researched the vibration of rotating blades modelled as anisotropic thin-walled beams containing piezoelectric materials through the proportional control law and velocity control law. Banerjee et.al.[9] derived exact expressions for the frequency equation and mode shapes of composite Timoshenko beams with cantilever end conditions in explicit analytical form by using symbolic computation.

II.INTRODUCTION TO WORK

Smart structures have wide application in shape control, vibration reduction and health monitoring because of their self-sensing and self-actuating capabilities. Normally, 1D modeling is sufficient to capture the essential features of the box beam.

A cantilever composite box beam with 0^0 and 90^0 plies is used for both Eigenvalue analysis and Rotating condition analysis. The following is the schematic of the glass-epoxy box beam.

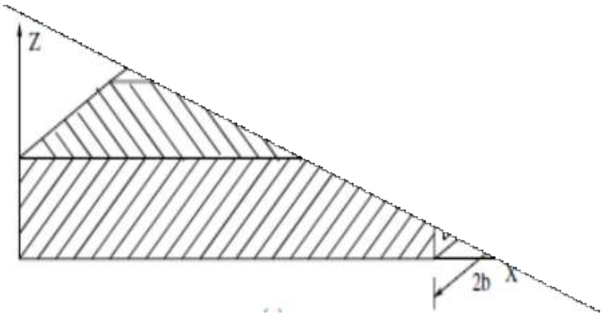


Fig.1 Schematic of composite box beam

The table shows the material properties and dimensions of the [$0_3/90_2/0_3$] glass-epoxy box beam (test speciman)

Material Properties	
E_{11} (GPa)	23.69
E_{22} (GPa)	7.63
$G_{12}=G_{13}=G_{23}$ (GPa)	3.37
υ_{12}	0.26
Density ,ρ (kg m^{-3})	1985

Dimensions	
Length, L (m)	0.655
Width (2b) (m)	0.057
Depth (2h) (m)	0.019
Ply thickness, t_p (m)	0.00025

Rotating composite beam structures like blades are applied in many fields of aerospace and mechanical engineering. The formulation for vibration control of the beams is based on the single cell composite beam, including a eigenvalue, centrifugal force, Coriolis forces, Spin softening effect. Furthermore, influences of parameters, such as rotating speeds, displacements of the beam, and fiber orientations in host structure are studied.

III. THE METHODOLOGY

Modal analysis of COMSOL Multiphysics is used to determine the Eigenvalue and mode shapes, which are important parameters in the design of a structure for dynamic loading conditions. Modalanalysis in COMSOL Multiphysics is Structural Mechanics. Here two conditions are studied to check the performance of composite box beam.
One is the Rotating Conditions of beam and other is Eigenvalue Analysis.

On the **Rotated System** , we have define the rotation relative to the global Cartesian coordinate system. In 3D models, we have specified the local coordinate system (***x*₁, *y*₁, *z*₁**) using three consecutive Euler angles (rotation angles) **α , β, γ.**

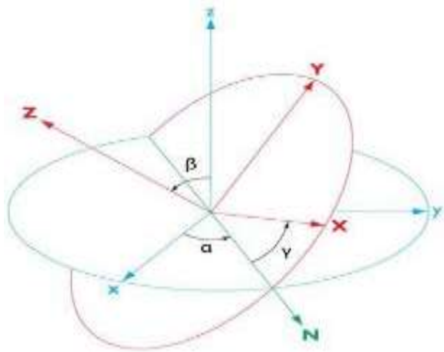


Fig. 2 ***3D*** Euler angles in a rotated coordinate system

In case of eigenvalue analysis, we have given the different angular velocities for the beam. The eigenvalue solver extracts the Jacobian, the damping matrix, and the mass matrix through Taylor expansion of the problem with respect to the eigenvalue variable around a specified eigenvalue linearization point (which is zero by default. Eigenvalue variable as a constant with value zero, unless it is set by an eigenvalue solution used as initial solution For many physics interfaces, the default is to use an eigenfrequency study and compute and display the eigen frequencies rather than the eigenvalues.

With the help of above mentioned material properties of the composite beam simulation is carried out.

The analysis is carried out using the structural Solid mechanics software. Structured meshing method is used for meshing the geometry. A normal mesh is used for meshing the 3D geometry of composite box beam with eight layer modification.

The simulation is done with the assumption of following boundary conditions.

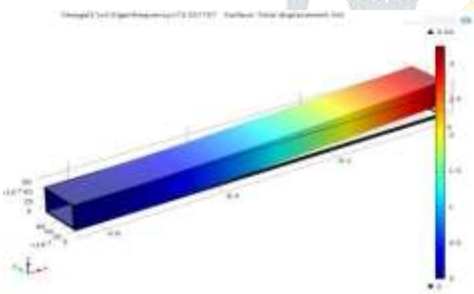
Rotated system	α	β	γ
Rotated system Upper Positive	θ= 45	0	0
Rotated system lower negative	θ= -45	0	0
Rotated system Side Positive	θ= 45	90	0
Rotated system Side negative	θ= -45	-90	0

IV.INFLUENCE OF EIGENVALUES ON COMPOSITE BOX BEAM

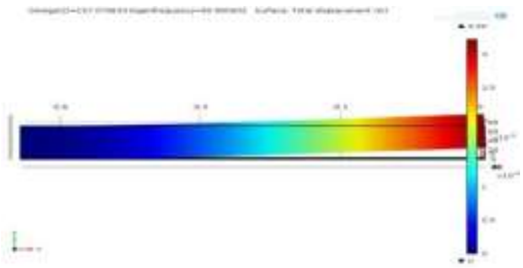
The different angular velocities are used forgetting. Different mode shapes associated with its eigenfrequency values.

Eigen frequency value of Composite Box Beam	
Omega (rad/s)	**Eigen frequency(Hz)**
0	73.557707
157.079633	90.990602
314.159265	417.76902
471.24	549.30559
628.318531	704.010006
785.398163	1040.539096
942.477796	1033.539209
1099.557429	1040.537529

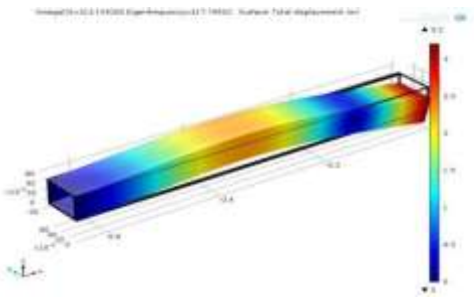
The different mode shapes for Eigenvalues are as follows:



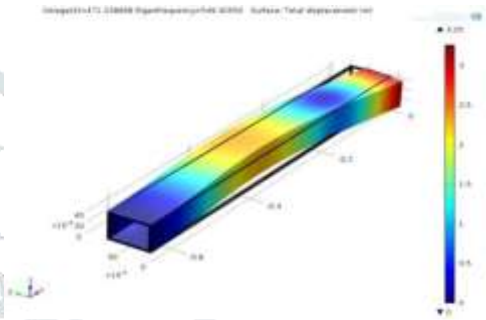
1st Mode – 73.55Hz



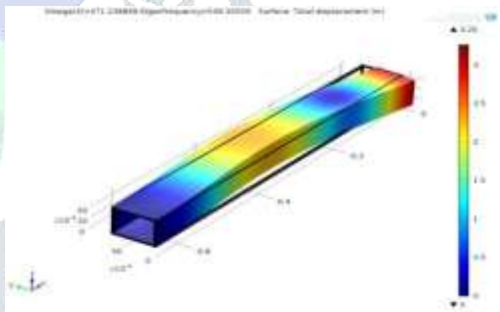
2nd Mode – 90.99Hz



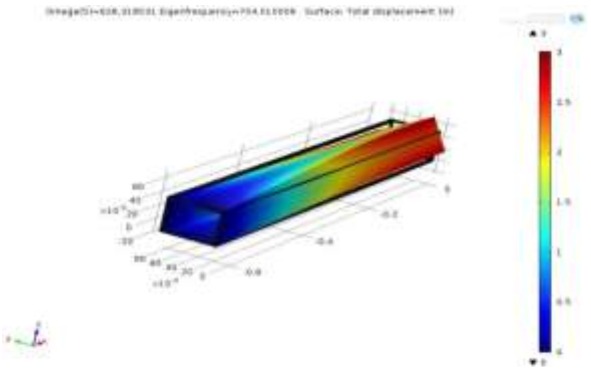
3rd Mode – 417.76Hz



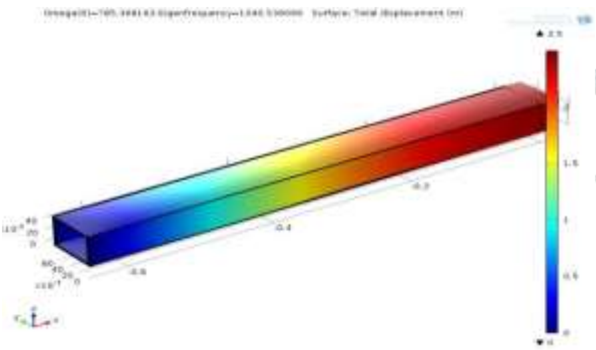
4th Mode – 549.30Hz



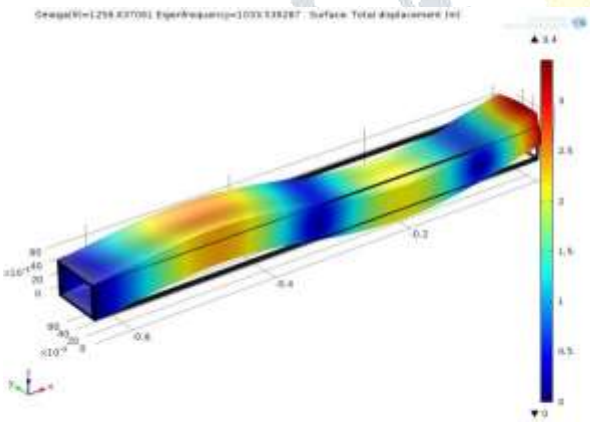
5th Mode –704.01Hz



6th Mode –1040.5390Hz



7th Mode –1033.53Hz



8th Mode –1040.5375Hz

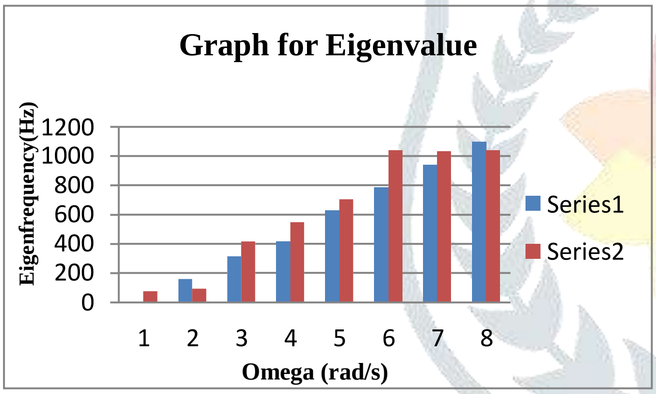
V. ROTATING CONDITION ANALYSIS

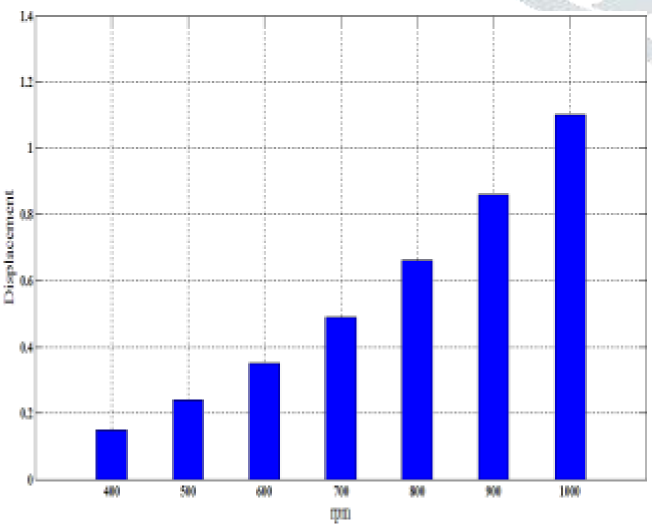
We have also checked the displacement beam fordifferent rotational speed.

Rotating Condition Results	
Rpm	**Displacement(mm)**
400	0.15
500	0.24
600	0.35
700	0.49
800	0.66
900	0.86
1000	1.1
1500	4.02
2000	11.4
2500	6.51
3000	7.17

VI .RESULTS AND DISCUSSIONS

The simulation results of the above shown composite box beam are presented in the graphs as follows.





The simulation results of eigenvalue analysis show that as the angular speed is increasing the eigenfrequency is also increasing. Eigenfrequency this would refer to the rotational frequency at which you would have the largest amount of vibration**,** which could also be called the resonant frequency. Eigen frequency can also be thought of as the normal modes in which a system vibrates.

So, eigenfrequency1 is taking the vibrations in to considerations. And also as the rotational speed is increasing the displacements is taking place as considering the vibrations in to account.

VII CONCLUSIONS

This paper is concerned with obtaining the eigen frequencies and mode shapes of composite beams. These vibration characteristics are of great and fundamental importance in structural dynamic analyses. Accurate determination of these characteristics is required in the design process to avoid resonances. They are also widely used in series solutions of aeroelastic response and stability problems. Naturally, a primary goal of this study is to attempt to understand the different modes of composite beams in which the affect the frequencies and the deformation pattern within each mode. A secondary aspect of the present study is the question of how differences in the modes of rotational analysis and eigenvalue analysis. (which arise due to assumptions imposed in the manner of their calculations) influence the predicted natural frequencies and mode shapes.

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