Free Vibration Characteristics Analysis of Prediction Modal Orthotropic Curved Panel by Using Finite Element Method

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ABSTRACT

The curved panels are used in modern structural system, because the shape control of structures achieves the desired performance. The static and dynamic instability behavior of curved panels made of advanced composite materials are of great importance to designers, in the quest to produce efficient light weight structures due to their high stiffness to weight and strength to weight properties. Some of the structural components of aircraft, missile and marine structures can be idealized as curved panels. The composite curved panels are extensively used in aerospace, civil, mechanical, automotive and other engineering applications. The fundamental natural frequency of composite curved panels highly depends on the ply orientations, geometries, edge forces. So the study of dynamic behavior of curved panels subjected to out-plane static and periodic edge loadings are very important in research and application point of view.

This work presents a simulation study of free vibration of curved panels. A comparison was made between isotropic and orthotropic curved panels in view of reducing the weight of the isotropic curved panels. The modal characteristics of isotropic (Aluminium) and orthotropic (carbon-epoxy composite) curved panels with cantilever boundary condition (one end is fixed and another one end is free) has been analyzed. The characteristics of composite material varies depending on the type of the applied material, quantity, fiber orientation angle etc. The natural frequency and mode shape of the panels has been obtained using ANSYS. Mindlin eight-node is oparametric layered shell elements (SHELL 99) are employed in the modeling for describing the bending vibrations of these curved panels. The influence of fiber directions and stacking arrangements of laminates on out-of-plane vibrations were investigated. The curved panel simulation results of the isotropic materials are compared with the orthotropic materials under cantilever plate boundary conditions with various fiber angle orientation and stacking sequence. It is also obtained that the natural frequencies change with the change of orientation angle.

KEY WORDS: Free vibration, Curved panel, Finite element method, Modal analysis, Harmonic analysis.

1. INTRODUCTION

Characteristics of Curved Structure: In general, engineering problems are mathematical models of physical situations. Thin-walled curved structures attracted lots of researchers‟ interests. Various mathematics models were developed generally based on spatial form geometries such as curved beams, curved plates and shells. These models are analyzed to reveal their features, which make them recognizable as useful objects in engineering.

The curved beam is usually modelled in one dimension, by neglecting the lateral motion. The complexity of the curved beam primarily comes from the curvature which is not only involved in the geometrical parameter, but also has impact on the resultant stress, stiffness and displacement functions. The curvature along with the arc-length direction can be either constant or variable. It is still straightforward to analyze constant curved structures; by contrast, the variation in curvature brings mathematical difficulties and even nonlinearity considerations into equations of motion. Sorted by curvature, curved beams appear in different shapes like circular, parabolic, elliptic, s-shaped and so on. The curved beam can be also classified by the type of cross section, such as symmetrical, unsymmetrical, continuously varying or hybrid. For the two-dimensional configuration, the terminology of "curved plate", also called "shell panel" is referring to a shell having small changes in slope of the un-deformed middle surface. The analysis of the curved plate is usually based on thin shell theory which is applied when the thickness is relatively small compared to its other dimensions and in which deformations are not large compared to thickness. The curved plate has curvatures in two dimensions, which could be variable or constant in either direction.

Advantages of Curved Structure: This large amount of engineering applications is mainly due to the following advantages of the curved structure;

- Significant span capacity can be achieved;
- In addition to the slenderness, curved beam or shell structures own high compression-resistance characteristics allowing advantageous dynamic and stability capacities;
- Variable curvature configuration expands the structure design flexibility and fashionable look;
- To apply walls as thin as possible is a natural optimization strategy to reduce dead load and minimize construction material;
- Significant benefits of using composite materials are expected to result in a 30-40% weight savings and a 10-30% cost reduction compared to conventional metallic structure.

System Modeling: The finite element modeling of curved panel are done using ANSYS software. It has been modeled to isotropic material properties and orthotropic material properties. In orthotropic material three layer can be used. In this case, different fiber angle and varying stacking sequence are considered.

2. MATERIALS AND METHODS

Construction: The d Isotropic material and Orthotropic material properties are following their,

Table.1. Isotropic Material Properties

Material	Young's modulus(N/m^2)	Density(kg/m^3)
Aluminium	70E+9	2710

Table.2. Orthotropic Material Properties

Material	E_1 (Gpa)	E_2 (Gpa)	G_{12}=G_{13} (Gpa)	G_{23} (Gpa)	V_{12}	Density (kg/m^3)
Carbon/Epoxy composite	128	11	4.48	1.53	0.25	1500

System Dimensions:

Table.3. Geometrical Properties of Curved Panel

Length of the panel	260 mm
Thickness of the base layer	0.56 mm
Radius of curvature	151 mm
Included angle	52°
Density of the base layer	2710 kg/m^3

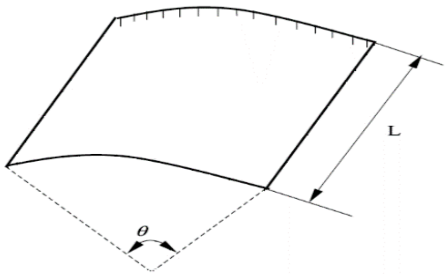


Figure .1. Curved Panel

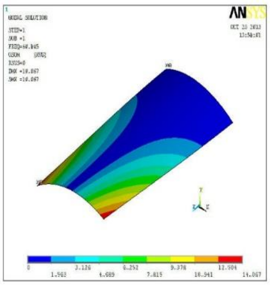
Finite Element Analysis (FEA) involves the mathematical modeling of a physical system to predict the structural both static and dynamic behavior of the system involving geometry, material properties, boundary conditions, etc. The model is used to determine what the new natural frequencies of the system will be after structural modification such as the orientation of the fiber angle and number of layer is applied. The model can be as simple or extensive as required.

In cases where a curved panel does not have sufficient capacity to perform up to the targeted condition, FEA can be used to predict the response at these higher condition or targeted condition.

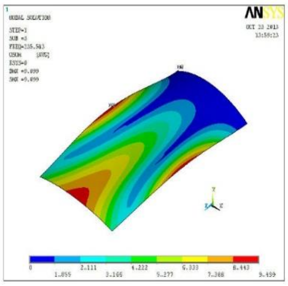
3. RESULTS AND DISCUSSIONS

The characteristics of composite material varies depending on the type of the applied material, quantity, fiber orientation angle etc. The natural frequency and mode shape of the panels has been obtained using ANSYS. Mindlin eight-node isoparametric layered shell elements (SHELL 99) are employed in the modeling for describing the bending vibrations of these curved panels. The influence of fiber directions and stacking arrangements of laminates on out-of-plane vibrations were investigated. The curved panel simulation results of the isotropic materials are compared with the orthotropic materials under cantilever plate boundary conditions with various fiber angle orientation and stacking sequence. It is also obtained that the natural frequencies change with the change of orientation angle.

Modal Analysis: The first step of the project is to complete a modal analysis of curved panel with the isotropic and orthotropic material properties. In this case fixed-free boundary condition used. The different results are taken and are tabulated. The following are some of the modal results obtained from the different stacking sequence and fiber angle orientation. Isotropic model result was approximately matched to the Orthotropic stacking sequence 0°/45°/0°.



Mode1



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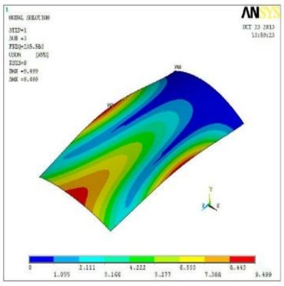

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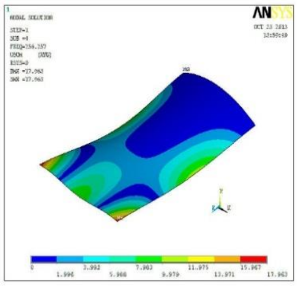
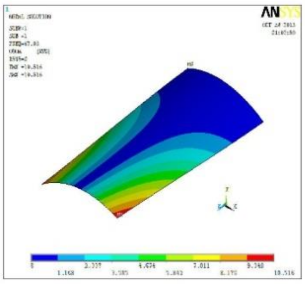


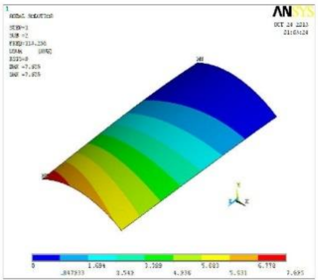
Mode 4

Figure.2. Isotropic Material Modal Analysis Result

Harmonic Analysis: The harmonic analysis is done after the modal analysis has been taken on the curved panels. The following are the various harmonic analysis results for the different fiber angle orientation and varying stacking sequence are analyzed by using ANSYS software.



Mode 1



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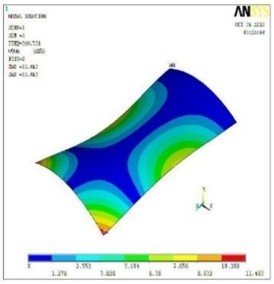

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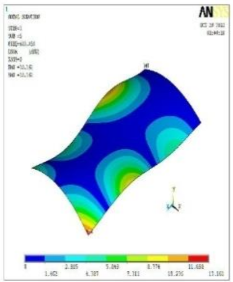

Mode 4

Figure.3. Orthotropic Material Modal Analysis Result-Stacking Sequence 0°/45°/0°

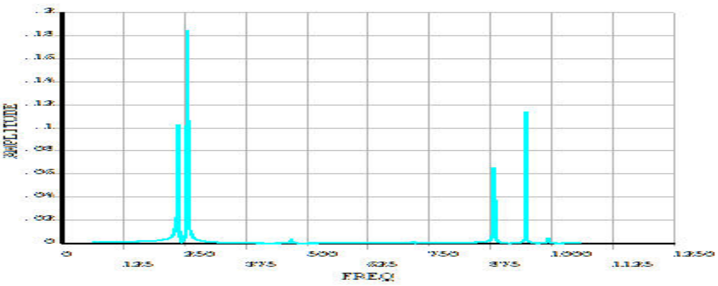

Figure.4. Isotropic Material Harmonic Analysis Result

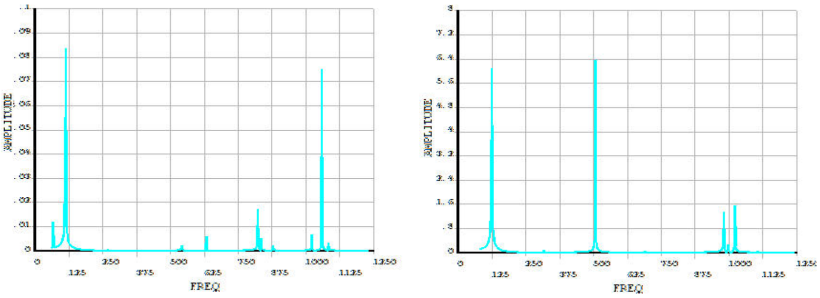

Figure.5. Orthotropic Material Harmonic Analysis Result-Stacking Sequence 0°/45°/0° and 0°/45°/-45°

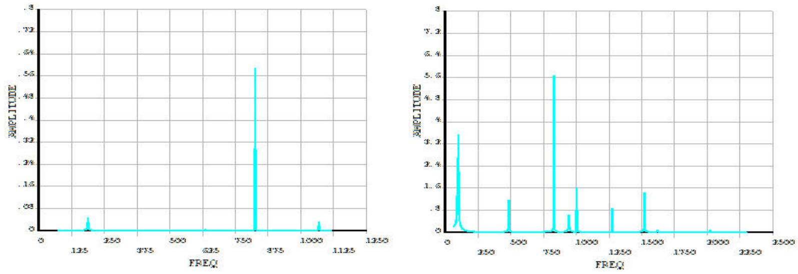

Figure.6. Orthotropic Material Harmonic Analysis Result-Stacking Sequence 0°/90°/0° and 0°/0°/0°

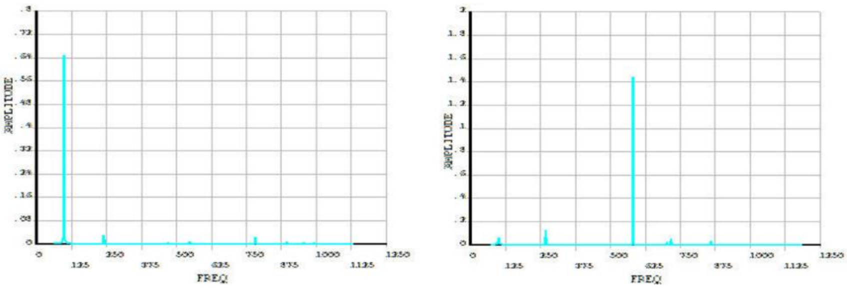

Figure.7. Orthotropic Material Harmonic Analysis Result-Stacking Sequence 15°/15°/15° and 30°/30°/30°

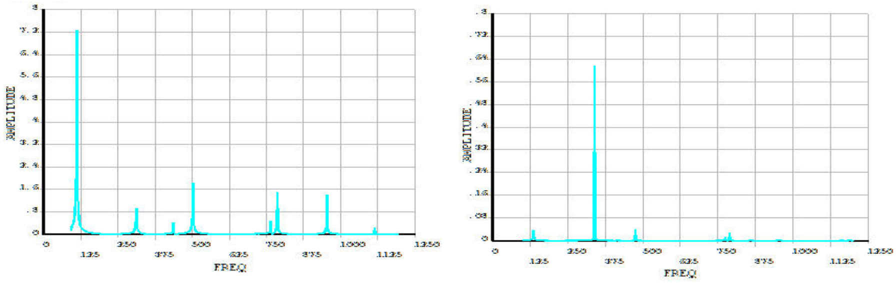

Figure.8. Orthotropic Material Harmonic Analysis Result-Stacking Sequence 45°/45°/45° and 60°/60°/60°

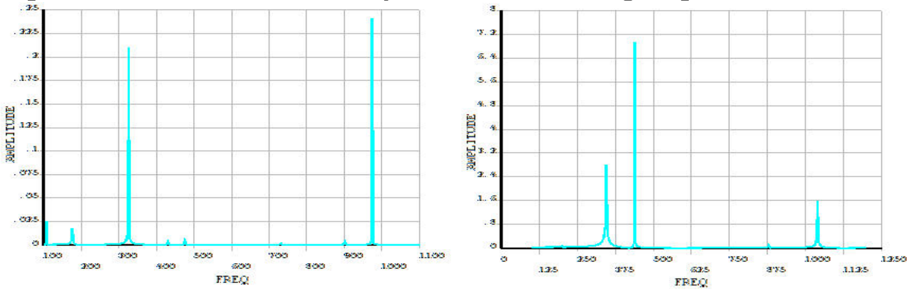

Figure.9. Orthotropic Material Harmonic Analysis Result-Stacking Sequence 75°/75°/75° and 90°/90°/90°

Validation: In this case Curved Panel are treated with Isotropic material and Orthotropic material. In Orthotropic material curved panel Modal Analysis and Harmonic Analysis are calculated with various stacking sequence and various fiber angle orientation. One edge is Clamped and another one edge is Free (Cantilever boundary condition) is used. In orthotropic three layers can be used. In this case natural frequencies change with change of orientation angle and stacking sequence. The following table shows the different result for different modes of the systems modeled and analyzed using ANSYS software.

Table.4. Comparison of Isotropic Modal Result to NavinKumar (2012)

S.no	Mode number	Literature	Present result
1	1	60	64.845
2	2	120	130.74
3	3	193	235.58
4	4	243	256.26

4. CONCLUSIONS

Free vibration analysis of curved panels is carried out using finite element method. Isotropic and Orthotropic panels and the influence of boundary conditions on the natural frequency of curved panels are analyzed.

- It is clear that changes in fiber angle as well as stacking sequences yield to different dynamic behavior of the component, that is, different natural frequencies for the same geometry, mass and boundary conditions. Since it makes possible to obtain the desired natural frequencies without increasing mass or changing geometry.
- The finite element software package ANSYS is an efficient simulation tool, because of its ability to model the curved panel fundamental modal frequencies and modal shapes. (By using of shell element SHELL99), it is useful for simplexes (saving of computing time).
- Finally this study is useful for the designer in order to select the fiber orientation angle to shift the natural frequencies as desired or to control the vibration level. We can use various properties of orthotropic materials and that change in fiber angle as well as stacking sequences to produce different dynamic behavior of the component, that is, different natural frequencies for the same geometry, mass and boundary conditions**.**

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