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PARAMETRIC STUDY ON THE FREE VIBRATION RESPONSE OF LAMINATED COMPOSITE BEAMS

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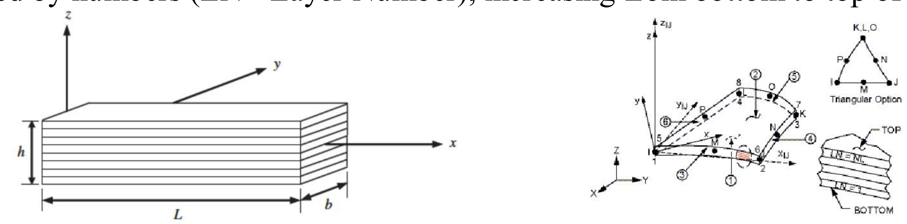
Summary. *In this work, a numerical study using finite elements is performed to investigate the free vibration response of laminated composite beams. We perform a dynamic modeling of the laminated beams by an eigenvalue analysis, using an eight-node layered shell element to simulate the free vibrations. A variety of parametric studies are carried out to see the effects of various changes in the laminate parameters on the natural frequencies of out-of-plane bending, torsional, and in-plane bending vibrations. The parameters investigated include the effects of fiber orientation, stacking sequence, span-to-thickness ratio, number of layers, modulus ratio, and support condition. The present parametric study is of major importance for the mechanical designer to conceive and optimize composite structures subjected to dynamic loadings.*

1 INTRODUCTION

Composites are the most promising materials for components of current and future engineering structures, with a significant demand at present in the aircraft and aerospace industries. A variety of structural components made of composite materials such as turbine blades, vehicle axles, robot arms, aircraft wings, and helicopter blades can be approximated as laminated composite beams; understanding their behavior under dynamical conditions requires a deeper understanding of the vibration characteristics of the composite beams. The aim of this work is to study and analyze the free vibration characteristics of general laminated composite beams using the FE software ANSYS. Many authors have used the FE technique to analyze the vibration of laminated beams [1, 2]. It appears that most of previous studies were focusing on the out-of-plane bending vibration; in contrast to those studies and as a novel aspect, the present work addresses in detail a parametric study on the free vibration of laminated beams including out-of-plane bending, torsional and in-plane bending frequencies. The geometry of the composite beam under study is pictured in figure 1a. The beam is made of many plies of orthotropic materials, and the principal material axes of a ply may be oriented at an arbitrary angle β with respect to the x-axis. The length, height and width of the beam are represented by parameters L, h and b, respectively. A 8-noded, linear layered 3-dimensional structural shell element (shell 99) is used for the modelling as shown in figure 1b. This element has six degrees of freedom at each node and is constituted by layers that are designated by numbers (LN - Layer Number), increasing from bottom to top of the laminate.



(a) **(b)**

Figure 1: (a) Geometry and coordinates of the laminated composite beam. (b) Shell99 geometry.

2 CONCLUSION: PRINCIPAL RESULTS

The main conclusions that can be drawn from this study are:

- The changes in fiber angle as well as laminate stacking sequences lead to different dynamic behaviors of the component, that is, different natural frequencies 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 more (or less) structure stiffness. Out-of plane and in-plane bending frequencies decrease, in general, as the fiber angle increases; the maximum occur at $\beta = 0°$. Furthermore, torsional frequencies increase with increasing the fiber angle, up to a significant value at about $\beta = 45°$; beyond this angle, the torsional frequencies decrease gradually with increasing the fiber angle up to a minimum value obtained for $\beta = 90°$.
- The increase of the beam length results in a decrease in the natural frequencies of out-of-plane bending, in-plane bending, and torsional vibrations of beams.
- As the number of layers increases, the out-of-plane bending and torsional natural frequencies increase slightly, and no change occurs for the in-plane natural frequencies.
- Boundary conditions have a remarkable influence on the natural frequencies. The natural frequencies for the clamped-clamped support are the highest. Clamped-simply supported, simply supported-simply supported, and clamped–free supports take the second, third, and fourth positions, respectively.
- An increase of the extensional modulus E_1 leads to an increase of the natural frequencies of the beam, which considerably affects the higher frequencies. For the flexural frequencies, the effect of fiber angle is more apparent at lower angles and it has no effect over 60°.

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