Free vibration of laminated composite and sandwich plate with eccentric circular cutout

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1. INTRODUCTION & OBJECTIVE

Laminated Composite is one of the very popular composites in engineering applications all over the world. Due to its excellent properties of high stiffness to weight ratio and low maintenance cost it is used in many engineering fields like aerospace, civil, automotive, naval etc. It comprises of different laminas or plies formed by matrix and fiber oriented in different angles as required. On the other hand, the sandwich materials are very light in weight. It consists of face sheets, core and adhesive interface layers. The face sheets resist in-plane and bending loads whereas core prevents shear loads. The core material taken is generally low or moderately stiff. These materials are considered as a good thermal and acoustical insulator.

Plate is very important structural parts. Cutouts are very useful for different purposes like manufacturing, fabrications and maintenances. It is necessary to study the vibration behaviour of the said structure for secure and safe designs. Sometimes, the cutouts are not placed centrally which causes significant changes in the dynamic behavior. Hence, the plate with eccentric cutout needs to be analyzed for dynamic responses for understanding the nature of the structure.

The main objective of this study is to perform the free vibration analysis of laminated composite sandwich plate structures with eccentric circular cutout to show the effect of fibre angles, core to skin thickness, overall thickness and boundary conditions on the natural frequencies and mode shapes.

2. METHOD OF ANALYSIS

A laminated composite plate of thickness *h* consisting of unidirectional lamina bonded together to act as an integral part as shown in Fig. 1.

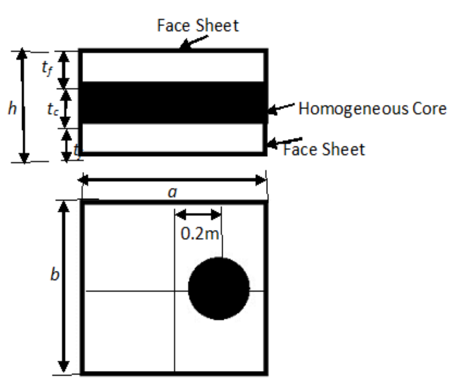


Figure 1. The LC Sandwich plate with cutout

Eight-noded isoparametric serendipity elements are used for the finite element analysis. Five degrees of freedom (u, v, w, θ_x, θ_y-three translations and two rotations) at each node has been used. The displacement functions using first order shear deformation theory (FSDT) are given as follows.

$$u(x,y,z) = u_0(x,y) + z\theta_x,$$

$$v(x,y,z) = v_0(x,y) + z\theta_y,$$

$$w = w_0$$

$$\emptyset_x = \theta_x - w_{,x}, \emptyset_y = \theta_y - w_{,y} \qquad [1]$$

Here, $u_0(x,y), v_0(x,y)$ and $w_0(x,y)$ are corresponding mid plane displacements. θ_x and θ_y, are rotations of the normal to the midplane in the *x-z* and *y-z* planes, respectively. $\emptyset_x$ and $\emptyset_y$ are the constant shear strains at *x-z* plane and *y-z* plane, respectively. The stiffness matrix and mass matrix are formed using layer wise theory in MATLAB. The differential equations for free vibration analysis are formulated from Energy principle.

3. RESULTS & HIGHLIGHTS OF IMPORTANT POINTS

A case study is carried out to analyze the behaviour of simply supported (SSSS) laminated composite sandwich plate with eccentric circular cutout. A 1m x 1m square plate with 0.1m radius of circular cutout with centre at a distance 0.2m from centre of the plate has been taken (refer Fig. 1). Materials for face sheets and core are E-glass epoxy and polyurethane core [2] respectively. The core *(c)* material properties are related to composite material properties *(f)* as follows: $E_{2f}/E_{1c} = E_{2f}/E_{2c} = E_{2f}/G_{12c} = E_{2f}/G_{23c} = E_{2f}/E_{13c} = 27.7$, $\upsilon_{12} = \upsilon_{21} = 0.35$, ρ_c=121.874 Kg m^{-3} and ρ_f=17.79 Kg m$^{-3.}$

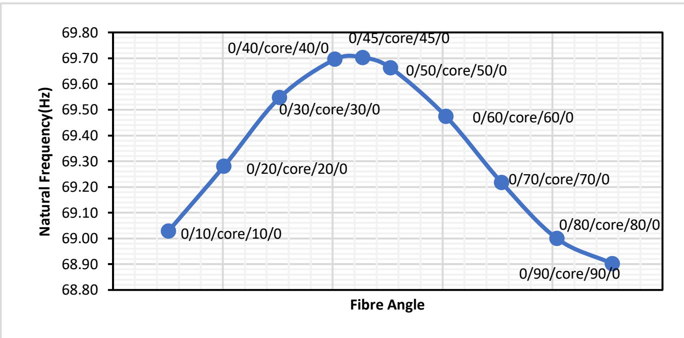
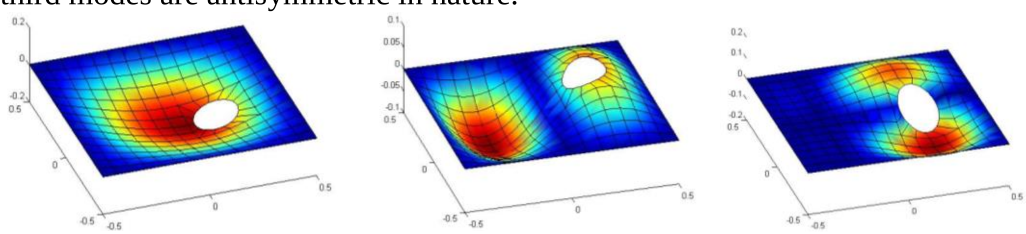


Figure 2. Variation of natural frequency (Hz) for different values of θ for simply supported plate with eccentric cutout

The configuration of the sandwich plate is taken as *0/θ/core/θ/0* where θ is varied as 10°, 20°, 30°, 40°, 45°, 50°, 60°, 70°, 80° and 90°. Figure 2 represents the variation of natural frequencies for different values of θ. It is noticed that the natural frequency and stiffness increases up to θ=45°. After that the natural frequency decreases indicating increase in flexibility. Figure 3 shows first three mode shapes for the previous case study. It is observed that the first mode is a symmetric bending mode whereas the second and third modes are antisymmetric in nature.



Mode 1 Mode 2 Mode 3

Figure 3. First three mode shapes

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2. S. Pal and A. Guha Niyogi, *Application of Folded Plate Formulation in Analyzing Stiffened Laminated Composite and Sandwich Folded Plate Vibration,* Journal of Reinforced Plastics and Composites, 2008.