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Free vibration behavior of laminated composite stiffened elliptic parabolic shell panel with cutout

Abstract: In this paper free vibration behavior of laminated composite stiffened elliptic parabolic shell has been analyzed in terms of natural frequency and mode shape. Finite element method has been applied using an eight-noded curved quadratic isoparametric element for shell with a three noded curved beam element for stiffener. Cross and angle ply shells with different edge conditions have been studied varying the size and position of the cutouts to arrive at a set of inferences of practical engineering significances.

Keywords: laminated composites; elliptic parabolic shell; cutout; stiffener; free vibration; finite element

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1 Introduction

The analysis of thin shells attracted attention of researchers from the first half of the nineteenth century. While the theory of shell structures was being improved from time to time by many researchers, another group of researchers started developing exotic materials with high strength and stiffness properties. This resulted in the use of laminated composite materials to fabricate shell forms. The researchers had realized that the configuration like folded plates, conoidal, saddle, spherical, elliptic and hyperbolic parabolic and hypar shells can offer a number of parallel advantages that suit to the requirements of the industry. In fact in industrial applications a shell may have complicated boundary conditions and may be subjected to complex loading. The advent of high speed computers in the second half of the twentieth century was a major development which paved the way of researchers to get involved in analysis and design of shells of arbitrary geometry and loading conditions using numerical techniques. Ghosh and Bandyopadhyay [1], Dey et al. [2, 3], Chakravorty et al. [4, 5] reported static and dynamic behaviour of laminated doubly curved shells. Later Nayak and Bandyopadhyay [6–8], Das and Chakravorty [9–12] and Pradyumna and Bandyopadhyay [12–14] reported static, dynamic and instability behavior of laminated doubly curved shells. The shell surfaces are often provided with cutouts for various functional requirements. Such shells need to be stiffened for avoiding stress concentration around cutouts. As the numerical approaches like finite element method become popular, investigators started venturing to analyze stiffened shells with cutout. Earlier studies in this aspect were due to Reddy [15], Malhotra et al. [16] and Sivasubramonian et al. [17]. They analyzed the effect of cutouts on the natural frequencies of plates. Later Sivakumar et al. [18], Rossi [19], Huang and Sakiyama [20] and Hota and Padhi [21] studied free vibration of plate with various cutout geometries. Researchers like, Chakravorty et al. [22], Sivasubramonian et al. [23], Hota and Chakravorty [24], Nanda and Bandyopadhyay [25] published useful information about free vibration of shells with cutout.

Shells of double curvature, particularly elliptic paraboloids, have the ability to span over relatively large distances without the need of intermediate supports in comparison with flat plates and cylindrical panels of the same general proportions. This aspect in particular attracts the designers to use such shell forms in places of large column free areas. Moreover, elliptic parabolic shells are both architecturally acceptable and structurally stiff due to their surface geometry. Qatu et al. [26] reviewed the work done on the vibration aspects of composite shells between 2000-2009 and observed that most of the researchers dealt with closed cylindrical shells. Other shell geometries like conical shells and shallow shells on rectangular, triangular, trapezoidal, circular, elliptical, rhombic or other planforms are receiving considerable attention. Recently, Kumar et al. [27–30] considered finite element formulation for shell analysis based on higher order zigzag theory. Vibration analysis of spherical shells and panels both shallow and deep has also been reported for different boundary conditions [31–34]. A complete and general view on mathematical modeling of laminated

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