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Relative Performance of Laminated Composite Doubly Curved Shell Roofs with Cutout

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Abstract

Performance characteristics of stiffened composite doubly curved shells with cutout are analyzed in terms of natural frequency. A finite element code is developed for the purpose by combining an eight noded curved shell element with a three noded curved beam element. The code is validated by solving benchmark problems available in the literature and comparing the results. The size of the cutout is varied for different edge constraints of cross-ply and angle-ply laminated composite shells. The results furnished here may be readily used by practicing engineers dealing with stiffened composite conoids, hyperbolic paraboloids and elliptic paraboloids with cutouts.

Keywords

Laminated Composite, Doubly Curved Shells, Cutout, Fundamental Frequency

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1. Introduction

Laminated composite structures have gained extensive importance in various fields of aerospace, marine and civil engineering. Shell roof structures can be conveniently built with composite materials that have many advantages, besides high specific strength and stiffness. Among the different shell panels which are commonly used as roofing units in civil engineering practice, the conoidal, hyperbolic paraboloidal among the anticlastic, and the elliptic paraboloidal among the synclastic shells are common as roofing units to cover large column-free areas. Conoidal shells being ruled surfaces provide ease of casting and allow north light to come in. Thus these are preferred in many situations. The hyperbolic paraboloidal shells are aesthetically appealing. But they are less stiff than other doubly curved shells. The elliptic paraboloidal shells, on the other hand, are architecturally acceptable as well as structurally stiff due to their surface geometry.

Research on conoidal shell was started long back with [1], who analysed static characteristics of conoidal shells using the variational method. Then it was continued and improved by researchers like Brebbia and Hadid [2], Choi [3], Ghosh and Bandyopadhyay [4, 5], Dey et al. [6] and Das and Bandyopadhyay [7]. Dey et al. [6] considered static analysis of conoidal shell while Chakravorty and Bandyopadhyay [8] applied the finite element technique to explore the free vibration characteristics of shallow conoids and also observed the effects of excluding some of the inertia terms from the mass matrix on the first four natural frequencies. Chakravorty et al. [9-11] published a series of papers where they reported on free and forced vibration characteristics of graphite-epoxy composite conoidal shells with regular boundary conditions. Later, Nayak and Bandyopadhyay [12-15] reported free vibration of stiffened isotropic and composite conoidal shells. Das Chakravorty [16, 17] considered bending and free vibration characteristics of un-punctured and un-stiffened composite conoids. Hota and Chakravorty [18] studied isotropic punctured conoidal shells with complicated boundary conditions along the four edges but no such study about composite conoidal shells is available in the literature. Number of researchers has worked on different behavioral

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