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Research Article

Dynamic Characters of Stiffened Composite Conoidal Shell Roofs with Cutouts: Design Aids and Selection Guidelines

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Dynamic characteristics of stiffened composite conoidal shells with cutout are analyzed in terms of the natural frequency and mode shapes. 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 cutouts and their positions with respect to the shell centre are varied for different edge constraints of cross-ply and angle-ply laminated composite conoids. The effects of these parametric variations on the fundamental frequencies and mode shapes are considered in details. The results furnished here may be readily used by practicing engineers dealing with stiffened composite conoids with cutouts central or eccentric.

1. Introduction

Laminated composite structures are gaining wide importance in various fields of aerospace and civil engineering. Shell roof structures can be conveniently built with composite materials that have many attributes, besides high specific strength and stiffness. Among the different shell panels which are commonly used as roofing units in civil engineering practice, the conoidal shell has a special position due to a number of advantages it offers. Conoidal shells are often used to cover large column-free areas. Being ruled surfaces, they provide ease of casting and also allow north light in. Hence, this shell is preferred in many places, particularly in medical, chemical, and food processing industries where entry of north light is desirable. Application of conoids in these industries often necessitates cutouts for the passage of light, service lines, and also sometimes for alteration of resonant frequency. In practice, the margin of the cutouts must be stiffened to take account of stress concentration effects. An in-depth study including bending, buckling, vibration, and impact is required to exploit the possibilities of these curved forms. The present investigation is, however, restricted only to the free vibration behaviour. A generalized formulation for the doubly curved laminated composite shell has been presented using the eight-noded curved quadratic isoparametric finite element including three radii of curvature. Some of the important contributions on the investigation of conoidal shells are briefly reviewed here.

The research on conoidal shell started about four decades ago. In 1964, Hadid [1] analysed static characteristics of conoidal shells using the variational method. The research was carried forward 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] provided a significant contribution on static analysis of conoidal shell. Chakravorty et al. [8] applied the finite element technique to explore the free vibration characteristics of shallow isotropic 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 and Chakravorty [16, 17] considered bending and free vibration characteristics of unpunctured and unstiffened 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