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Fundamental Frequency of Composite Hypar Shell with Stiffener: Optimization of Stiffener Arrangement

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Abstract*:* An eight noded shell element combined with a three noded beam element is used to study the free vibration behaviour of laminated composite stiffened hypar shells. A variety of problems are solved taking simply supported boundary conditions. Free vibration response of stiffened composite hypar shells is studied with respect to fundamental frequency by varying the number and depth of stiffeners. The results are further analysed to suggest guidelines to select optimum stiffener arrangement.

Keywords: hypar shell, stiffened, free vibration, finite element analysis, laminated composite

1. Introduction

Skewed hypar shells (Fig. 1) can offer a number of civil engineering advantages particularly when the material is laminated composite with high strength to weight ratio. The hypar shells may be stiffened to have enhanced rigidity when subjected to point loads or provided with cutouts for some service requirements. Sinha and Mukhopadhyay [1] echoed this fact in their review paper. The initial studies about vibrations of stiffened shell panels were about cylindrical shells. Recently Nayak and Bandyopadhyay [2,3] carried out free vibration studies of isotropic stiffened shell panels in details including stiffened hypar shells. Free and forced vibrations of unstiffened composite hypar shell was reported by Chakravorty et al. [4]. Sahoo and Chakravorty [5] presented results of static analysis of stiffened composite hypar shells.

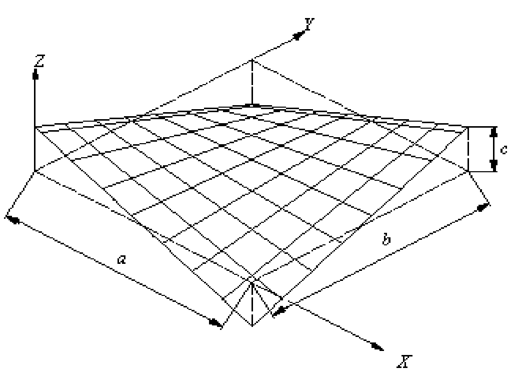

Fig.1 Surface of a skewed hypar shell

Surface equation: $z = \frac{4c}{ab}\left(x - \frac{a}{2}\right)\left(y - \frac{b}{2}\right)$

An overall look at the volume of literature that has accumulated till date dealing with stiffened shell panels reflect the fact that vibration of stiffened composite skewed hypar shells have not received due attention by researchers. This, no doubt, defines a wide area of research and the present paper attempts towards suggesting guidelines for optimization of stiffener arrangement to minimize the material consumption of composite hypar shells with respect to fundamental frequency.

2. Mathematical Formulation

The stiffened shell element is formulated by combining an eight noded shell bending element and three noded curved beam element and the systematic development of the stiffness and mass matrices are reported elsewhere [6]. The same paper reports about the validation of the formulation through solution of benchmark problems.

A laminated composite hypar shell of uniform thickness h and twist radius of curvature R_{xy} is considered. Keeping the total thickness same, the thickness may consist of any number of thin laminae each of which may be arbitrarily oriented at an angle θ with reference to the x-axis of the co-ordinate system. An eight-noded curved quadratic isoparametric finite element is used for hypar shell analysis. The five degrees of freedom taken into consideration at each node are u, v, w, α, β. Sahoo and Chakravorty [5] reported the strain displacement and constitutive relationships together with the systematic development of stiffness matrix for the shell element.

Three noded curved isoparametric beam elements are used to model the stiffeners, which are taken to run only along the boundaries of the shell elements. In the stiffener element, each node has four degrees of freedom i.e. usx, wsx, αsx and βsx for x-stiffener and usy, wsy, αsy,and βsy for y-stiffener. The generalized force-displacement relation of stiffeners can be expressed as: