Optimization of Stiffened Laminated Composite Rhombic Elliptical Paraboloidal shells for Nonlinear Bending Performance

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The literature reveals that research studies on stiffened laminated composite elliptical paraboloids (Figure 1) are scanty, particularly for the rhombic geometries. These panels are often preferred in civil, maritime, and aerospace structures for their ability to cover longer spans with fewer supports. Since the moderately thin panels can undergo large deformations under static overloading, a geometrically nonlinear approach is essential for realistic performance predictions. Performance can be improved by stiffeners. Since stiffened panels are costlier than bare ones, this study presents an optimization analysis which reports deflections and stresses for varying weight ratios of stiffened to the bare panels. The Nonlinear solutions are obtained using an isoparametric C^0 continues finite element code based on von-Karman type nonlinear strains and first order shear deformation theory. The optimization study aims for achieving panels with minimizing the weight ratio while restricting the deflections and stresses within serviceable limits.

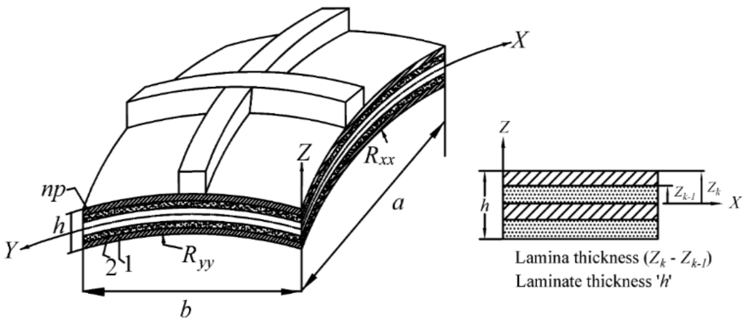

Figure 1: Stiffened elliptic paraboloidal panel

The nonlinear bending problem is solved using Newton-Raphson iterative approach [1]. The incremental displacement for the n^{th} iteration is given as follows,

$$\Delta\{\delta\}_n = [K_T]^{-1}\left\{\sum_{j=1}^{ne}(\{R\} - [K_s]\{\delta\})_j\right\} \tag{1}$$

The secant stiffness matrix is given in the following:

$$[K_s] = \int_A [T]^T[\overline{B}]^T\left[[E]\left([B\,]^L + \frac{1}{2}[B\,]^{NL}\right)[T]\{\delta\}\right] dA \tag{2}$$

The improved solution can be obtained from the given equation.

$$\{\delta\}_{n+1} = \{\delta\}_n + \Delta\{\delta\}_n \tag{3}$$

[1] N. Singh and K. Bakshi, Nonlinear bending of laminated composite rhombic stiffened elliptical paraboloids, Mechanics of Advanced Materials and Structures, 33(1), 2621138, 2026. https://doi.org/10.1080/15376494.2026.2621138