

POSTBUCKLING AND VIBRATIONS OF COMPOSITE LAMINATED AXISYMMETRIC SHELLS

by

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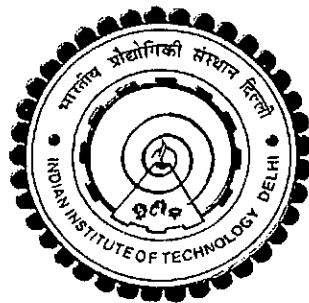
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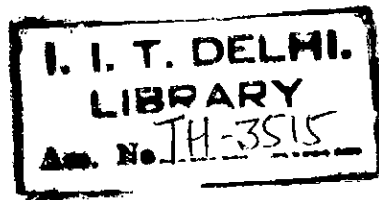
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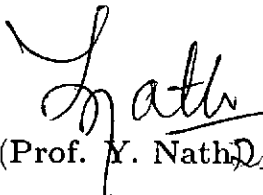
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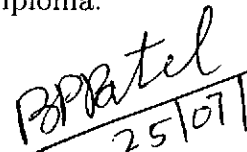
Dedicated
to
my parents

Certificate

This is to certify that the thesis entitled “**Postbuckling and Vibrations of Composite Laminated Axisymmetric Shells**” being submitted by Mr. Satyendra Singh to the **Indian Institute of Technology, Delhi** for the award of the degree of Doctor of Philosophy in Applied Mechanics is a record of original, bonafide research work carried out by him under our supervision and guidance. The thesis work, in our opinion, has reached the requisite standard fulfilling the requirements for the degree of Doctor of Philosophy.

The results contained in this thesis have not been submitted in part or in full, to any other University or Institute for the award of any degree or diploma.


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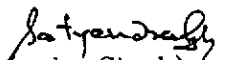
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Abstract

The laminated composite cylindrical shells with and without meridional curvature, conical and joined conical-cylindrical shells are increasingly being used in various engineering applications such as aerospace, marine, mechanical, nuclear and automotive engineering. These structures are often subjected to combined mechanical and thermal loading during their service life. The thermomechanical loading may induce a compressive membrane state of stress which may cause buckling. An estimate of the critical buckling load can be made through an eigenvalue analysis. In the traditional shell design approach, this critical buckling load is reduced by a knockdown factor [EN 1993-1-6, DIN 15018, BS 5500, ECCS-Recommendations] to account for mainly effect of imperfections. Sometimes this may result in overly conservative design or even potentially unsafe ones. Therefore, it is important to study the postbuckling behaviour to estimate the lowest safe load.

Vibration, buckling, and postbuckling analyses of laminated composite circular conical, cylindrical and joined conical-cylindrical shells subjected to torsional load, external pressure, axial compression and thermal load applied either individually or in combination are presented in the thesis. The analysis is carried out employing a computationally efficient semi-analytical finite element approach based on first order shear deformation theory and field consistency principle. The variation in stiffness coefficients along the meridional direction due to changes in ply-angle and ply-thickness of filament wound laminated conical shells is considered in the formulation. The nonlinear governing equations are derived incorporating Sanders type kinematic relations for small strains and moderately large rotations. The governing equations for von Kármán type of geometric nonlinearity can be deduced from Sanders theory by neglecting the appropriate terms and are solved for the purpose

of comparative study. The transverse shear and membrane strains are interpolated in a consistent manner using field redistributed substitute shape functions for accurate and locking free results. An estimate of critical buckling load is made by eigenvalue analysis. The postbuckling behaviour is evaluated by means of nonlinear analysis. The prebuckling and postbuckling equilibrium paths are traced by solving the governing equations using Newton-Raphson technique coupled with the adaptive displacement control method. For transient dynamic analysis the governing equations are solved employing Newmark's numerical integration technique. The presence of asymmetric perturbation in the form of small magnitude transverse load which is spatially proportional to a linear buckling mode shape is employed to initiate the bifurcation of the shell deformations from axisymmetric to asymmetric one in nonlinear static analysis.

The main contributions of the thesis are to analyze the influence of circumferential wave number, boundary conditions, ply-angle and semi-cone angle on i) buckling and postbuckling characteristics of filament wound cross-ply and angle-ply laminated composite conical and joined conical-cylindrical shells under thermomechanical loadings, ii) buckling and postbuckling behaviour of cross-ply and angle-ply laminated conical shells under combined (a) axial compression and external pressure, (b) thermal and external pressure, (c) axial compression, external pressure and torsional load, (d) thermal, external pressure and torsional load, iii) buckling and postbuckling behaviour of laminated cylindrical shells with meridional curvature under thermomechanical loadings, and iv) vibration and stability studies in pre and postbuckled equilibrium configurations of cross-ply heated conical and cylindrical shells. Several new results are presented in the thesis.

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