STABILITY AND DYNAMICS OF COMPOSITE PLATES AND CYLINDRICAL PANELS

by

RUPESH DARIPA

Department of Applied Mechanics

Submitted

in fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

to the

INDIAN INSTITUTE OF TECHNOLOGY DELHI

SEPTEMBER 2009

CERTIFICATE

This is to certify that the thesis entitled "***Stability And Dynamics of Composite Plates and Cylindrical Panels***", that is being submitted by **Shri Rupesh Daripa** to the Indian Institute of Technology Delhi for the award of the degree of *Doctor of Philosophy* is a record of original research work carried out by him under my guidance and supervision.

Shri Daripa has fulfilled all the prescribed requirements and the thesis is, in my opinion, worthy of consideration for the degree of *Doctor of Philosophy* in accordance with the regulations of the Institute.

The contents of this thesis have not been submitted to any other University or Institute for the award of any degree or diploma.

Dr. M. K. Singha
Assistant Professor
Department of Applied Mechanics
Indian Institute of Technology Delhi
New Delhi-110016
India

Place: New Delhi
Date:

ACKNOWLEDGEMENTS

First of all, I would like to sincerely and wholeheartedly thank my supervisor Dr. Maloy Kumar Singha, for his guidance and kindness throughout this work. He has been extremely helpful to me in providing high quality guidance, strong cooperation and advice on various aspects of my research work and other situations of life at various stages. I had a genuine scope of learning the best of him for which I sometimes consider myself lucky.

I would like to thank the members of my Doctoral research committee, Prof. Y. Nath, Prof. D. K. Sehgal and Prof. K Gupta for their valuable suggestions.

I am really thankful to all of my friends, S. D. kulkarni, S. Singh, Anish, Kallol, Ibrahim, Rizban, G. V. Rao, Tufan who helped me with material, moral and intellectual support at the time of need. Thanks are also due to Mr. V. S. Rawat and Mr. Kailash Chandra for their help with computational facilities in laboratory. I would like to take this opportunity to thank all those who helped me in whatever capacity to see that the present project attains a succecssfull completion.

Most importantly, I would like to thank my parents, for their unconditional support, love, and affection. Their encouragement and neverending kindness made everything easier to achieve. A special thanks to my elder brother and sisters for providing me constant support and encouragement.

Rupesh Daripa

Abstract

Plates and shells, made of isotropic or laminated composite materials are used as major load carrying components of aerospace, automobile, submarine, civil, offshore and other important engineering structures. Hence, the stability and dynamic characteristics of such thin-walled structures is an important problem to be understood well for their effective and lightweight design.

In this thesis, an attempt is made to investigate some of the characteristic features of the nonlinear stability and dynamics of plates and cylindrical shell panels using the shear deformable finite element approach. For this purpose, one high precision shear flexible plate bending element with fourteen degrees of freedom per node is developed. The nonlinear stiffness matrix is formulated based on von Kármán's strain-displacement assumptions to obtain the stiffness interaction (coupling) between the in-plane and bending degrees of freedom. Then, the plate bending element is modified using Marguerre's strain-displacement assumptions and a shallow shell element is obtained. Further, the sixteen-noded MITC (mixed interpolation of tensorial components) shell element based on assumed strain fields (initially proposed by *Bucalem and Bathe* 1993) is extended here for the nonlinear vibration analysis of composite cylindrical panels.

At the beginning, the critical buckling load and the subsequent posubuckling behavior (*i.e.*, the lateral displacement and end-shortening) of isotropic and composite plates under static in-plane load are studied in this thesis. Numerical investigation is focused to investigate the influences of (a) different in-plane boundary conditions, (b) per-buckling corner stresses in the skew plate, (c) position and distribution of

localized in-plane edge load for the rectangular plate, (d) lamination parameter and (e) sinusoidal imperfection.

Nonlinear dynamics of plates and shells is a complex phenomenon involving both flexural vibration and in-plane strain. Attempt is made in this thesis to obtain the steady-state un-damped vibration characteristics of composite plates and shell panels. Approximate time functions (corresponding to a steady-state periodic oscillation) for the displacement components are assumed and a nonlinear matrix amplitude equation is obtained by employing Galerkin's method. The coupled nonlinear matrix amplitude equation (in-plane motion is coupled with flexural motion) is solved to estimate

(a) nonlinear free flexural vibration frequencies of isotropic and composite plates with different in-plane boundary conditions,
(b) flexural vibration amplitudes of such plates under transverse harmonic pressure,
(c) flexural vibration amplitudes of such plates under periodic in-plane load,
(d) vibration amplitude *versus* disturbing energy relationship for the case of free flexural vibration of cylindrical shell panels,
(e) Frequency-amplitude relationship of cylindrical shell panels under radial harmonic pressure.

Finally, the time history analysis is carried out in each case to understand the steady-state or unsteady nature of the flexural vibration of plates and shell panels under different loading and boundary condition.

1 TABLE OF CONTENTS

CHAPTER: 6

CHAPTER: 7

CHAPTER: 8

CHAPTER: 9