Nonlinear Structural Analysis

Foreword

This special issue of *Sadhana* is a collection of five papers selected from those presented at the Eighth National Seminar on Aerospace Structures (8^{th} NASAS) organised by and held at the Indian Institute of Technology Madras, Chennai, on 9–10 October 1998.

The Structures Panel of the Aeronautics Research and Development Board of India organises the National Seminar on Aerospace Structures (NASAS) organised by and every year on a specific theme. The theme of 8^{th} NASAS was "Nonlinear Mechanics". During the last half-century, nonlinear problems of mechanics and mathematical physics have attracted considerable attention. Earlier, almost all phenomenological studies were solved using linear or linearised systems. However, rapid advances in science and engineering have pushed frontiers of technology to such extents that linear theories no longer suffice. This is the case in aerospace structures where the use of low rigidity thin-walled structures results in large deformations governed by nonlinear differential equations. The solution of such models by approximate analytical or computational techniques has also become very important.

About forty papers (4 invited and 36 contributed) were presented at the National Seminar. A great variety of topics was covered, including themes such as nonlinear finite element analysis, composite structures, fracture mechanics, vibration, chaos, contact stresses etc. In this issue, five papers have been specially invited to be presented in full-length form, covering nonlinear structural analysis. An interesting mix results, showing the emerging preferences and thrust directions. Only one is based on an analytical approach while four papers use the finite element methodology. All deal with thin/thick plate, panel or shell structures, and three are on the composite form of construction, highlighting the remarkable success and acceptance this form of design has had in the recent past in aerospace and aeronautical engineering. Statics, dynamics, buckling, limit point and bifurcation stability, and delamination tolerance are covered in this sample.

It is appropriate that the series starts with Nath and Sandeep using the traditional but not forgotten analytical approach judiciously combined with computational algorithms to tackle nonlinear behaviour described by von Karman–Donnell thin shell equations of doubly curved thin isotropic shells on rectangular planforms. The spatial discretisation is based on Chebyshev polynomials with the implicit Houbolt time-marching scheme to predict the response. Both static and dynamic results are presented.

In the second paper, Krishnam Raju and Nagabhushanam extend the Integrated Force Method (IFM) of finite element analysis to nonlinear structural analysis. The IFM has been offered for some time as a useful alternative to the more familiar displacement-based finite element method and has been usefully utilised in linear structural analysis, including dynamics and optimisation problems. Here, a general formulation of the nonlinear problem is presented and some significantly nonlinear benchmark problems demonstrate the accuracy and efficiency of this approach.

Gajbir Singh and Venkateswara Rao introduce the concept of a material finite element (MFE) with six engineering degrees of freedom. Unlike the conventional displacement-based

approaches where the shape functions depend only on the placement of the nodes, here they become functions of various structural interactions, i.e. extensional, bending-extensional, bending and transverse shear stiffnesses. The element is very attractively found to be free of shear locking and applications to the large amplitude dynamic behaviour of unsymmetrically laminated plates are demonstrated.

Prema Kumar and Palaninathan examine the geometric nonlinear behaviour of laminated composite cylindrical panels, using a finite element formulation based on thick shell elements, which offer a more accurate representation of the through-thickness structural behaviour as well. Whereas conventional formulations use numerical integration in the thickness direction in each layer and are computationally expensive, the authors here consider the expedient of using explicit through-thickness integration, examining various levels of approximation. The limit point and bifurcation behaviour of panels for various parameters like number of layers, sequence of lay-up, boundary conditions etc. are investigated.

The series closes with an investigation of delamination tolerance based on fracture mechanics principles in laminated composite panels by Singh, Dattaguru, Ramamurthy and Mangalgiri. This is very important in defining acceptability criteria for the use of such construction in primary aerospace and aircraft structures. Three-dimensional finite element software based on the 8-noded brick element was developed to analyse circular and elliptical delaminations. Large deformation considerations (geometric nonlinearity) are invoked to monitor the post-buckling response of delaminated sub-laminates. Fracture mechanics is introduced through the strain energy release rate and modified virtual crack closure integral representation. Numerical results show where delamination is critical.

The task of organising this special issue was first assumed by the late Professor K A V Pandalai, a doyen of such studies in the country. However, failing health prevented him from completing this assignment. Professor Pandalai passed away last year and we hope that this special issue will remember him for championing the cause of nonlinear structural analysis over nearly four decades of research and teaching.

The Guest Editors are thankful to the authors for the effort and care taken to arrange to submit full-length versions of their original seminar presentations and also to the reviewers who helped to ensure that the papers maintain the standard and style of the journal so that its archival value is assured.

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