Abstract

The work presented in this dissertation describes the static and dynamic instability behaviour of flat and curved panels (both isotropic and composite) under non-uniform in-plane conservative and nonconservative follower edge loading. The non-uniform edge loading and the discontinuities in the panel produce complex non-uniform initial (pre-buckle) in-plane stress state within the panel. The nature of initial stress distribution plays a very important role in both static and dynamic stability behaviour of the panels.

Elastic systems may be classified into conservative and nonconservative systems, depending on the forces acting on the system. Conservative systems can lose the stability of their equilibrium positions by divergence (static stability) only, whereas nonconservative systems can have two types of instability mechanisms – divergence (static instability) and flutter (dynamic instability). The destabilizing effect of small damping in structures subjected to nonconservative loading is perhaps one of the most interesting problems in structural dynamics, involving dynamic instability behaviour.

In the present investigation the flutter and divergence loads are obtained by means of modal analysis. In the analysis many weak instabilities are found; a weak instability corresponds to a critical load which is significantly smaller than the strong flutter load. The effects of damping are studied because small damping may destabilize the nonconservative system. The flutter load with small damping is drastically lower than that without damping.

The theory used for the formulation of the problem is the extension of dynamic shear deformable theory according to Sanders' first approximation for doubly curved shells, which can be reduced to Love's and Donnell's theories by means of tracers. The first order shear deformation theory (FSDT) is used to model the curved panels, considering the effects of transverse shear deformation and rotary inertia. To discretise the continuum and then to use finite element approach, an eight-node curved isoparametric quadratic element is employed in the present analysis with five degrees of freedom per node. Element elastic, mass and stress/geometric stiffness matrices are derived with the help of

suitable interpolation functions within the element and integrating various expressions over the element area by using the Gauss quadrature numerical integration technique. Since the stress field is non-uniform, due to arbitrary nature of the applied in-plane load and due to the presence of opening in the panel, plane stress analysis has been carried out using the finite element method to determine the state of in-plane stress distribution. This state of stress is then used to generate the geometric stiffness matrix. The various element level matrices have been assembled in skyline form to generate the corresponding global system matrices.

The study is analytical in nature. The solution of the problem is quite complex due to various parameters like curved geometry, non-uniform as well as discrete loadings, unsymmetrical boundary conditions, orthotropy, damping and geometrical discontinuity.

In the present investigation, a general purpose finite element formulation has been worked out for solving any complex structural static and dynamic stability problem. The formulation encompasses a variety of parameters such as isotropy, anisotropy, geometry (flat and curved panels), discontinuity (openings), nature of forces (conservative tensile and compressive forces, follower force), effect of damping, load direction control parameter and boundary conditions.

Analytical results are presented to show the effects of geometry, boundary conditions, load and other important parameters. The effect of circular cutout on static, dynamic instability is also presented. Comparison of the results has been made with the available literature, wherever possible. Conclusions are drawn highlighting the important findings of the study.

The thesis has been organized into five chapters. **Chapter 1** includes the general introduction and importance of the present work.

The review of literature confirming to the scope of present study has been highlighted in **Chapter 2**. The important works done and the general methods of solution of vibration and stability problems of plates and shells under conservative and nonconservative force systems have been briefly indicated in this chapter after critical discussions of the references.

Chapter 3 comprises of the mathematical formulation of the problem based on Hamilton’s principle. Finite element technique has been used for the development and solution of the problem for evaluating the vibration, buckling, parametric instability and flutter characteristics of the curved panel.

Case studies involving vibration and stability behaviour of undamped and damped flat and curved panels subjected to non-uniform conservative and follower forces with direction control have been taken and the results with discussions are presented in **Chapter 4.** Prior to the actual solution of the above problems, validation of the formulation and solution procedure have been carried out with the help of known results and, also, by means of convergence criterion.

The important conclusions drawn from the present investigation and possible scope of extension of the present work have been presented in **Chapter 5**.

A list of important reference books, papers and articles are listed in the **Bibliography** section. At the end, the important features along with flow charts and analytical concepts of eigenvalue characteristics for nonconservative force system are explained in the appendix.

Key words: Buckling, circular cutout, composite, divergence, dynamic stability, doubly curved panel, finite element method, follower load, flutter, in-plane load, local buckling, parametric resonance, vibration.