ABSTRACT

The work presented in this thesis is concerned mainly with the static and dynamic instability characteristics of plates under various types of non-uniform in-plane and follower edge loading. The non-uniform edge loading produces complex non-uniform initial (pre-buckle) in-plane stress state within the plate. The nature of initial stress distribution plays an important role in both static and dynamic stability behaviour of plates.

A finite element formulation based on the Mindlin's plate theory is used to derive the governing equations for the dynamic behaviour of plates. An eight noded isoparametric element is employed for plates without cut-outs. Plates with cut-outs involve some highly distorted elements in its discretization. Hence a nine noded element which is known to give better performance under the distorted element geometry is employed for plates with cut-outs. The stiffness, mass and geometric stiffness matrices for the elements are derived by using suitable interpolation functions (shape functions) within the elements and integrating various energy expressions over the element area by using a Gauss quadrature numerical integration technique. The element matrices are assembled into global matrices and stored into a skyline storage form. Various energy equations are expressed in terms of global finite element matrices and global nodal displacement vector. Hamilton's principle and Lagrange's equation are then used to obtain the equilibrium equation in terms of finite element matrices, governing the motion of the plate. The governing equations for the problems of buckling, vibration, parametric excitation are derived from the general equilibrium equation.

A modal transformation is applied to the governing equation for the parametric excitation problems mainly for two reasons : (a) to reduce the size of the original equation to a computationally effective size and (b) to transform the equation into a form suitable for the application of the method of multiple scales (MMS). The modal transformation is done by means of the normal modes obtained from the free vibration analysis Modal transformation also facilitates the definition and

inclusion of the modal damping matrix into the modal equilibrium equations.

A solution procedure for obtaining simple and combination parametric resonance regions is developed by using a perturbation method based on multiple time scales, MMS, which takes into account the effects of viscous as well as hysteretic (structural) damping upto the second order of the perturbation parameter (dynamic load factor).

The effects of follower loading into the governing equilibrium equation are included by using the extended Hamilton's principle which results in a non-self-adjoint eigenvalue problem. The boundaries of parametric resonance zones in this case are also obtained by the MMS.

Analytical results are obtained for the static and dynamic instability behaviour (simple and combination resonances) of plates for different non-uniform in-plane and follower loading, considering various parameters like, the nature of loading, static and dynamic load factors, aspect ratio, boundary conditions, etc. The effects of viscous and structural damping have also been considered.

Experiments on the parametric response behaviour of plates subjected to concentrated periodic loading at different edge locations are carried out and various instability zones have been established.

The results from both the analytical and experimental works are discussed and comparisons between the analytical and experimental works are made, whereever possible. Conclusions are made highlighting the important findings based on the analytical and experimental results.

Thesis organization : The entire thesis is organized into six chapters and an appendix. Chapter 1 gives an introduction to various dynamic instability problems of plates under in-plane and follower edge loading, a review of related literature and the aim and scope of the present investigations. Chapter 2 presents the finite element formulation, the governing equations and the methods of solution for the problems under consideration. Chapter 3 describes the computer codes written in FORTRAN 77 for implementation of the finite element formulation and to solve equilibrium equations corresponding to different problems. Detailed results and discussions on the dynamic instability characteristics of plates under in-plane and follower loads are given in Chapter 4. The experimental works on the response of plates under parametric excitation for few cases are described in Chapter 5. Fundamental conclusions drawn from the theoretical and experimental findings in the present investigation are listed in Chapter 6. A list of references cited in the text is given after the end of the last chapter. Appendix 1 presents the application of the MMS to parametric excitation problems.

Key words : In-plane loading, buckling, non-uniform loading, tension buckling, vibration, dynamic stability, natural frequencies, damping, parametric instability, resonance, instability regions/zones, simple and combination resonance, destabilizing effect, follower loading, flutter, divergence.