Chapter-1

Introduction

The uses of shell panels are common in many activities of aerospace, mechanical, civil and marine engineering structures. These structures experience in-plane forces in many situations. The presence of such loads significantly affects the free vibration characteristics of the structures. The buckling phenomenon may be considered as a particular case of free vibration problem with in-plane load, where as the load approaches towards its critical value of buckling, the frequency of vibration tends to zero. When the in-plane load becomes harmonic, it may lead to the condition of parametric resonance. It is found that certain combinations of the frequency of pulsating in-plane force and the natural frequencies of transverse vibration produce dynamic instability where the amplitude of the transverse vibration increases without bound. This phenomenon is entirely different from the usual resonance of forced vibration. In forced vibration when the frequency of the transverse forcing system matches with the natural frequency of the structure, resonance occurs. Thus the resonance phenomenon in forced vibration problem is relatively simple since the structure loses stability at constant frequencies of the transverse loads. On the other hand the instability in case of parametric resonance occurs over a range of frequencies of the in-plane force rather than a single value. Again parametric resonance of a structure may occur at load level much less than the static buckling load while the static instability of the structure sets in at the static buckling load values. Thus a structural component designed to withstand static buckling load may easily fail in an environment having periodic in-plane loading. So a designer ought to consider the parametric resonance aspect while dealing a structure subjected to dynamic loading atmosphere.

The use of composite material is steadily increasing in the present days due to its high strength/stiffness-to-weight ratio and these can be tailored through the variation of fiber orientation and stacking sequence to obtain an efficient design. In addition to that, the specific strength/stiffness of a panel can be enhanced by the use of a suitable stiffened structural form. These benefits have been exploited in the study of stiffened composite shell panel structure considered in the present investigation.

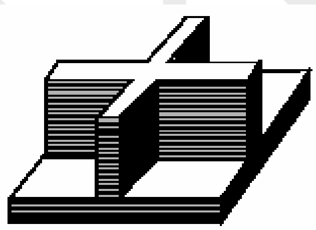
In lightweight metal construction such as aircraft, it has been observed that the in-plane loads are of considerable magnitude. These types of structures when stiffened can safely carry the loads even if the skin buckles. With more use of such structures buckling and dynamic instability analysis have gathered more importance. Moreover the in-plane loads are non-uniform in nature in many cases. Even if the applied stresses are uniform the stress distribution inside the panels becomes non-uniform due to the presence of stiffeners and different boundary conditions. The development of non-uniform patch loading can be understood from the discussion presented in the book by Bruhn [19]. Cases of practical interest arise when the in-plane stresses are caused by patch, triangular, point or any arbitrary forces acting along the boundary. Again the geometrical discontinuities like cutouts are inevitable in the aerospace, civil, mechanical and marine structures. In aerospace structures cutouts are commonly found as access ports for mechanical and electrical systems, or simply to reduce weight. Cutouts are sometimes provided for ventilation and to alter the resonant frequency of the structures. In addition, the designers often need to incorporate cutouts or openings to serve as doors and windows. In all these situations where the stress field is non-uniform, which may be either due to the non-uniform or discrete edge load, or due to the presence of different stiffening systems and boundary conditions, or due to the presence of discontinuities in the stiffened panels, the analysis for vibration, buckling and dynamic instability becomes quite complex. In such cases not only the stress field is non-uniform, the nature of the stresses may also be different in different regions. It is quite cumbersome and tedious to work out any closed form solutions to the aforesaid problems, though not impossible. Under these circumstances, one has to resort to some numerical techniques for the solution of these problems.

With the emergence of the digital computers, with their enormous computing speed and core memory capacity, the outlook of the structural analysts is being changed and helped in the evolution of various numerical methods such as the finite element, boundary element, finite strip, method of multiple scales. For treating arbitrary loading and boundary conditions, the finite element is known to be one of the suitable numerical methods because of its versatility. These numerical tools allow the researchers to model the structure in a more realistic manner with simpler mathematical forms.

The method of solution of dynamic stability class of problems discussed above involves first reducing the equations of motion to a system of Mathieu-Hill equations having periodic coefficients and the parametric resonance characteristics are studied from the solution of equations. Analytical solutions are available only for certain geometry, loading and boundary conditions. In general structural problem, the governing Mathieu-Hill equations lead to an infinite set of equations with unknown coefficients, which need to be truncated finite for finite degrees of freedom. The solution of dynamic stability of structures involves the determination of the eigenvalues corresponding to the instability regions by analytical methods or by numerical approach.

In order to model a shell panel without any significant approximation related to the representation of arbitrary shell geometry, structural deformation and other associated aspects, the isoparametric 3D degenerated shell element [1,160,119] having eight nodes is used. Though the concept of 3D degenerated shell element was initially proposed for isotropic shell [1] but it has been subsequently extended to the fiber reinforced laminated panels [106]. The present formulation differs from Panda and Natarajan [106] in the treatment of mapping in the thickness direction. Panda and Natarajan [106] have mapped the individual layers whereas the entire laminate is mapped in the present formulation. For the stiffeners, a compatible three-noded isoparametric curved beam element is used. The beam element is always placed along the edge of shell elements and this is intentionally not placed within the shell element in order to avoid the problem of stress jump within the shell element.

The basic concept underlying in the formulation of degenerated shell element [1] has been extended to derive beam/stiffener elements having any arbitrary curve geometry suitable for use in two or three-dimensional problems [35,13]. Again the formulation for isotropic beam [35,13] has been upgraded for laminated beam by Liao and Reddy [71] where the stiffener layers are stacked parallel to those of the shell (parallel stacking scheme). Unfortunately the 3D degenerated beam element based on the above formulation [35,13,71] has some problem in torsional mode since it overestimates torsonal rigidity [35]. The problem becomes more severe in case of stiffeners having narrow cross-section like blade stiffener, which is quite common in composite construction. Keeping this aspect in view, the stiffener element is reformulated where the above mentioned problem has been eliminated by using torsion correction factor. In order to achieve that the stiffener bending in the plane of the shell surface is neglected. This should not affect the solution accuracy since deformation of the stiffener in that plane will be very small due to high in-plane rigidity of the shell skin. Moreover, the new formulation has the advantage that it requires five degrees of freedom per node while it is six in case of existing formulations [35,13,71]. Actually the stiffener element will directly share the five nodal unknowns of the shell element. The beam element considered has a rectangular section where provision has been kept for parallel (Fig.1.1a) as well as perpendicular stacking schemes (Fig. 1.1b).



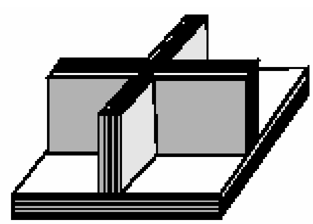


Fig. 1.1a Parallel stacking schemes **Fig. 1.1b Perpendicular stacking schemes**

It is clear from the above discussion that the process of investigating the different aspects of dynamic stability of laminated composite and isotropic stiffened shell panel structure is on, and, hence, a study of the dynamic stability behaviour of such structures is a problem of current interest. The problem involves different complicated effects such as geometry, boundary conditions, anisotropy and structures with discontinuity and non-uniform in-plane stress distribution. The above-discussed aspects need attention and thus constitute a problem of current interest.

In the present investigation the analysis for vibration, buckling (static stability) and dynamic stability of the isotropic and laminated composite stiffened shell panels with and/or without cutout are implemented by a computer program written in Fortran-90. An attempt has been made to make the program as general as possible to carryout any type of analysis within the scope of the present investigation. The compiler used is Microsoft Developer Studio.

A thorough review of early works done in this field is an important requirement to arrive at the objective and scope of the present investigation. The detail review of literature along with discussions is presented below.