CHAPTER 1

INTRODUCTION

1.1 Background

The composite materials have been in use for aerospace, marine, automobile, biomedical and civil structures for some time. This is due to their high specific strength and stiffness. Moreover, these materials can be tailored with respect to fibre orientation for efficient design of complex structures. Analyzing a complete structure is time consuming, costly and also, the desired output may not be observed. So, a part of the structure may be considered and analyzed for various conditions. Plates and cylindrical panels are part of large complex structures which are considered in the present investigation. During the service life of the complex structure, the plates and shell panels may be subjected to sudden loads in their own plane. Normally, these in-plane loads are transferred from their neighbouring components (Patel *et al.,* 2011; Panda and Ramachandra, 2011; Ramachandra and Panda, 2012; Kumar *et al.*, 2015;). For certain conditions, these in-plane loads can cause the components (plates and shell panels) to lose their stability, which can render the entire structure vulnerable to failure.

Instability in the structure can be caused due to either static loads or dynamic loads. Designing a structure for only static loads even though it is used in a dynamic environment may lead to economic design, however, the safety of the structure cannot be ensured. Instability caused due to static loads is termed as static buckling phenomenon. In the case of dynamic loads, if the loading is periodic (Fig.1.1), the instability is termed as parametric instability. Another type of instability caused due to pulse loads (Fig. 1.2) in the structure is called dynamic buckling. In this case, the structure is subjected to load for a very short duration in the form of a pulse. The loss of stability due to suddenly applied in-plane pulse load is investigated in the present work. Figure 1.1 shows the load vs time plot for a problem related to parametric instability. The duration of the load is not finite. Figure 1.2 shows the load vs time plot for a problem related to dynamic buckling. In Fig. 1.2, a rectangular pulse load is shown. Figure 1.3

shows the typical change in deformation in a typical cylindrical panel due to the action of rectangular pulse load.

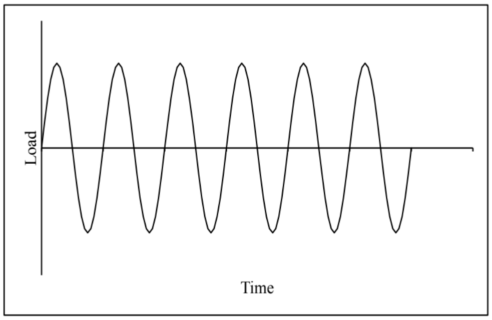

Fig. 1.1 Load vs Time plot for Parametric Instability analysis

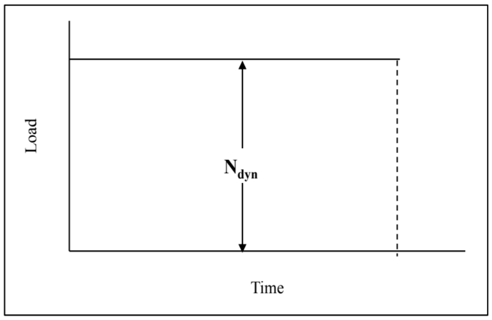

Fig. 1.2 Load vs Time for Dynamic Buckling analysis

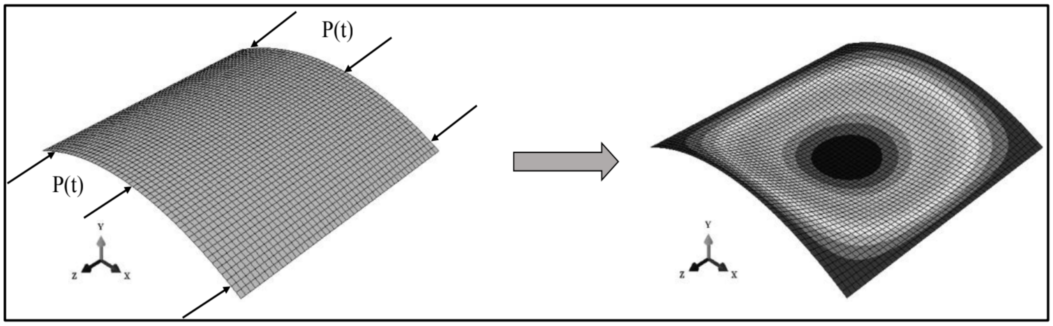

Fig. 1.3 Change in deformation due to the action of rectangular pulse load on a typical cylindrical panel

The duration and the amplitude of the loading are critical in structures subjected to dynamic loads. When the loading duration is very short (much lower than the fundamental period of the structure) and the magnitude of the load is very high, the phenomenon of impact is observed. If the duration is in the vicinity of the fundamental period of the structure, dynamic buckling occurs. Further, if the loading duration is very large, quasi-static behaviour is observed. Pulse loads may take a rectangular, triangular, sinusoidal, exponential or any other shape. These shapes correspond to a variety of problems considered to model the real dynamic loads. For example, pressure from a wave of hitting a ship is a sinusoidal pulse load. The waves hitting the bottom of a motor-boat are rectangular pulse loads. Explosions are described as the exponential pulse loads. Further, load variation during a nuclear explosion describes a triangular pulse load. In the present study, composite plates and cylindrical panels subjected to rectangular, sinusoidal and triangular pulse loads till their respective fundamental natural period are investigated.

Furthermore, cutouts are provided in laminated composite plates and cylindrical panels for carrying out utilities and in some cases, to reduce the weight of the structures. For this reason, the evaluation of the stability of plates and cylindrical panels with cutouts is essential. In the current investigation, the stability of laminated composite cylindrical panels with cutouts is investigated. Apart from these, in general, stiffeners are provided in shell structures to increase the stiffness of the structures. Hence, the influence of stiffener on the stability of cylindrical panels subjected to suddenly applied loads is also considered in this study.

In the current investigation, the first ply failure of laminated composite plates and cylindrical panels is evaluated along with their stability when subjected to suddenly applied in-plane loads. The stability and the first ply failure are the indicators of initiation of failure in the laminated composite plates and cylindrical panels. Thus, in the present investigation, the precedence of dynamic buckling load and the first ply failure load is checked. The influence of various parameters such as aspect ratio, curvature, stacking sequence, area of the cutout, shape of cutout and aspect ratio of the stiffener on the dynamic buckling behavior of the plates and cylindrical panels are investigated. The stability of structures has been investigated for decades using experimental, numerical and analytical methods.

The use of numerical methods and finite element method software packages help in obtaining reasonably accurate results for complex structures which are difficult to obtain using analytical methods or experimental methods. Simulation of structures subjected to short duration is efficiently done using dynamic Explicit finite element method which is based on the equation of motion approach.

The dynamic buckling criterion considered is Vol’mir criterion. This criterion is easy to use, and also, the results obtained from this criterion are comparable with the results from other dynamic buckling criteria. The details of Vol’mir criterion are presented in Chapter 4 (section 4.6). For the failure analysis, only the first ply failure load is calculated using four failure theories: Maximum Stress criterion, Azzi-Tsai-Hill criterion, Tsai-Hill criterion and Tsai-Wu criterion.

1.2 Motivation

The field of stability of structures subjected to dynamic loads was introduced to me by my supervisor. The research project sanctioned by CSIR and the need for investigation of stability and failure of structures subjected to in-plane pulse loads helped me in choosing the topic of my research work.

1.3 Aim of the Present Investigation

The study aims to investigate the stability of laminated composite plate and cylindrical panel when subjected to in-plane pulse load and to check if the plate or panel is stable at its first ply failure load. To achieve this objective, a detailed literature survey is necessary. The objectives of the thesis are presented in Chapter 2 after a detailed literature survey.

1.4 Organization of Thesis

This thesis consists of nine chapters. It is organized in the following manner.

Chapter 1 is the Introduction, which highlights the types of instability in the structure, need for investigating the dynamic buckling behavior of structures and the aim of the investigation.

In **Chapter 2**, the literature survey is presented on the stability of plate and cylindrical panels made of isotropic and composite materials. The studies related to the phenomenon of static buckling, parametric instability, dynamic buckling and failure of plates and cylindrical panels are reported. The objectives of the study are presented after the literature survey.

Chapter 3 presents the theory and the modelling considered in the study. The details regarding the modelling of composite materials and the procedures followed in the investigation are described in the chapter.

In **Chapter 4**, the problem description is provided. The details of geometry, boundary conditions and material properties are presented in this chapter.

In **Chapter 5**, the results of the dynamic buckling studies of laminated composite plates are presented. Additionally, the results of convergence and validation studies of static buckling load, dynamic buckling load and the shock spectrum of plates are presented.

Chapter 6 presents the results of the dynamic buckling behavior of laminated composite cylindrical panels. The influence of various parameters on the dynamic buckling behavior of cylindrical panels is investigated and presented.

Chapter 7 presents the results of the dynamic buckling behavior of laminated composite cylindrical panels with cutouts. The influence of various parameters including the shape and size of cutouts on the dynamic buckling behavior of cylindrical panels are studied and presented.

Chapter 8 presents the results of the dynamic buckling behavior of laminated composite stiffened cylindrical panels. The influence of various parameters including the aspect ratio of the stiffeners on the dynamic buckling behavior of cylindrical panels is investigated and presented.

In **Chapter 9**, the conclusions drawn from Chapters 5-8 are presented along with strengths, limitations, the impact of the present investigation on the research community and future scope of the study.