CHAPTER - 1

Introduction

1.1 General

Fiber reinforced polymer (FRP) has been used extensively in aircraft and automobiles area, design of lightweight structure and retrofitting of old structures. Generally, local buckling, global buckling and collapse of the stiffened panels occur under shear, compression load and their combination. The failure of stiffened panel initiates from the interface between plate and stiffeners due to stress induced by damage to plate and stiffeners after the local buckling. Influence on buckling strength of the stiffened panel with variation of the thickness of plate and stiffener can be studied using analytical method, finite element method (FEM) and experimental work. Critical Buckling and collapse loads are proportional to the flexural rigidity of the stiffened panel. The design of stiffened panel is governed both by stability and strength criterion. The laminated stiffened panels are being increasingly used in structural applications because of their high stiffness and specific strength. Stability of the plate is increased with increasing thickness of the plate but a more economical solution is obtained by keeping the thickness of plate as small as possible with addition of the stiffeners in the panel.

Linear buckling analysis on the laminated composite hat-stiffened panel with simply supported boundary conditions has been performed under edge compressive loading. Parametric studies on the stiffened panel has been carried out based on smeared stiffness approach for two different hat-stiffened (60^0-hat-stiffened and 75^0-hat-stiffened) panels with variation of pitch length and depth of stiffeners, panel orthotropy ratio and smeared extensional stiffness ratio of stiffeners to that of skin with different plies configuration. Also a good artificial neural network (ANN) is obtained after several iteration for prediction of the pre buckling load of the stiffened panel. Experimental studies on two laminated composite hat-stiffened panels have been conducted with application of axial compression load on the panel for the determination of the pre-buckling and post buckling behavior. A non-linear buckling analysis on the hat-stiffened panel has also been analyzed with application of finite element tool ABAQUS. Bakis et al. [1] presented the detailed studies on buckling of laminated composite stiffened structures and its applications in civil engineering.

1.2 Configuration of FRP Laminates

Composite material is made with two or more material combined layer wise to form a material having different properties than those of the individual materials. FRP is a laminated composite material having two constituents, a series of fibers surrounded by a cohesive bonding material. The FRP laminates can be of various thicknesses and consist of different constituent of the materials. Hence, the effective properties of the laminate vary with the angle of fiber orientation (0 degree, 90 degree, +/- θ^0 degree etc.), number of layers, thickness of each layer or ply. It is more convenient to analyze laminate composites by using common fixed system of coordinate s(x, y, z) also referred as the global coordinates. The orientation of ply is given by the angle between the global x -axis and the major principal material axis of the ply measured anti-clockwise direction on the x-y plane (in plane).

Table 1.1 Ply configuration of skin

Skin of laminated composite	Ply configuration (angle in degree)
Unidirectional 6 - ply Symmetric	$[0/0/0/0/0/0] = [0_6]$, $[0/30/60/60/30/0] = [0/30/60]_s$
Cross ply symmetric	$[0/90/90/0] = [0/90]_s$
Angle ply symmetric	$[+45/-45/-45/+45] = [\pm 45]_2$
Multi direction symmetric	$[[30/-30/90/0]_s]_s$, $[[45/-45/90/0]_s]_s$, $[[60/-60/90/0]_s]_s$,

Laminated composite are named by indicating the number of ply, thickness, orientation and stacking sequence of the plies. The configuration of the laminate indicating its ply composition is called lay-up. In addition to this, the configuration indicating the exact location or sequence of the various plies is called the stacking sequence. A few examples of ply configuration of skins are illustrated in Table 1.1. Ply configuration $[45^0/-45^0/90^0/0^0]_s]_s$ of 16 plies of the laminated composite is shown in Figure 1.1.

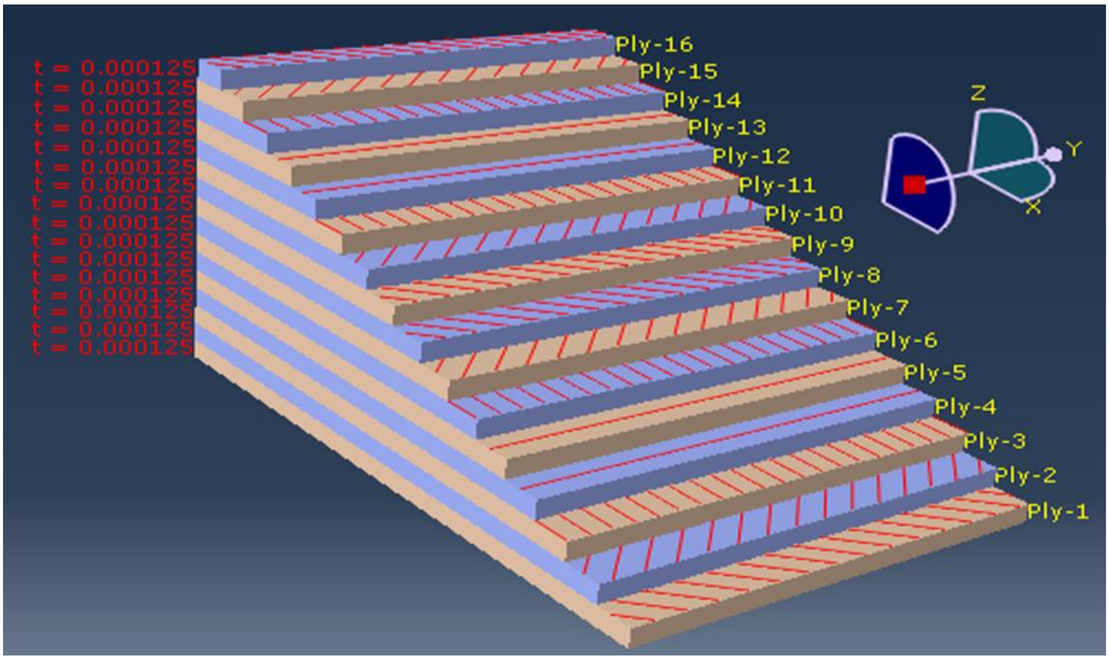

Figure 1.1 Ply configuration $[[45^0/-45^0/90^0/0^0]_s]_s$ of 16 plies of the laminated composite

1.3 Need of the Study

The aim of achieving a lightweight structure is an ongoing task for the engineering community. Fiber-reinforced polymers (FRP) meet this requirement to some extent since its development in 1960. FRP has been used extensively in defense, aircraft, and automobiles area and now it is currently being employed in structural applications. FRP stiffened panels have been being used as the load shared walls of the compressive member of structures, which possess load carrying strength after initial buckling until the ultimate strength of the composite material is reached. Composite panels have been also applied in multi-storey building to reduce the dead load of the structure. FRP laminated panels have been currently used in heritage buildings for retrofitting due to its high specific strength and aesthetic appearance.

1.4 Organization of Thesis

The thesis is organized into six chapters including the introduction.

Chapter 1: Introduction

This chapter provides introduction to details of general application of Fiber-reinforced polymers (FRP), need of the study and organization of this thesis.

Chapter 2: Review of Literature

This chapter deals with review on different methodology of the pre-buckling and post-buckling behaviour of laminated composite stiffened panels with damage. The review has been done on the basis of applications of the analytical method, experimental and computational, application of finite element method and development of other methods. Existing gaps in the study of laminated composite stiffened panels and objectives of research work have been discussed in this chapter.

Chapter 3: Numerical Studies on Thin Wall Laminated Composite Hat-Stiffened Panels under edge Compression Load

In this chapter, linear buckling numerical analysis on the laminated composite hat-stiffened panel under edge compression load has been performed with two different types, viz., 60^0-hat-stiffeners and 75^0-hat-stiffeners. Several parametric studies on buckling of the hat-stiffened panels have been carried out with variation of pitch length of stiffeners, number of stiffener, panel orthotropy ratio and smeared extensional stiffness ratio of stiffeners to that of skin with three different plies configuration. The optimum $(EA)_S/(EA)_P$ is studied for different orthotropy ratio D_1/D_2 and three different skin (A_{11}/A_{22}) of the panel for various buckling load per unit area of 60^0-hat and 75^0-hat-stiffened panels.

Chapter 4: The Prediction of Buckling Load of Laminated Composite Hat-Stiffened Panels under edge Compression Load by using Neural Networks

In this chapter, four different input variables A_{11}/A_{22}, D_1/D_2, D_3/D_2 and $(EA)_S/(EA)_P$ have been taken, which influence the buckling of the hat-stiffened panel under compressive load and buckling load per unit area taken as output for preparation of networks. The good artifial neural network architecture is achieved after several iterations to predict the buckling load of the stiffened panel. Hence, for unknown new data set, ANN prediction of buckling load per unit area is in good agreement with FEA results of different cases, which show that ANN tool can be used to design the complex structural problem in civil engineering and optimization of the laminated composite stiffened panel.

Chapter 5: Experimental and FE Analysis for the Post-Buckling Behaviour of Hat-Stiffened Panels under edge Compression Load

In this chapter, the pre-buckling and post buckling analyses has been performed on the hat-stiffened panel under in-plane compression by experiments as well as application of FE software ABAQUS. The strain gauges were installed on the skin and stiffeners of the stiffened panel for monitoring the buckling behaviour of the panel. The strain gauges were located on the panel in two patterns for determination of buckling behaviour of skin and stiffener. The experimental curve of compressive load-axial displacement is in good agreement with simulated FE model result for prediction of the buckling behaviour of the panel up to the failure load.

Chapter 6: Conclusions and future work

This chapter concludes the work reported in the thesis and discusses about future scopes of research work.