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Research Paper

Impact of the Lamination Scheme on the Laminated Composite Plate Buckling Load

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ABSTRACT: *The study of thin rectangular laminated composite plates subjected to the biaxial action of in-plane compressive stress is done using the finite element (FE) technique. A program written in Fortran has been created. By comparing the FE solutions for biaxial buckling of thin laminated rectangular plates with other theoretical solutions, the convergence and correctness of the solutions were confirmed. In order to quantify the impacts of lamination scheme, aspect ratio, material anisotropy, fiber orientation of layers, reversed lamination scheme, and boundary conditions, new numerical findings are produced for in-plane compressive biaxial buckling. Because of the link between bending and stretching, which lowers the buckling stresses of symmetric laminates, it was discovered that symmetric laminates are stiffer than anti-symmetric ones. As the aspect ratio rises, the buckling load rises, and as the modulus ratio rises, it falls. Even if the lamination sequence is switched, the buckling load won't change. Depending on the kind of end support, the buckling load rises with the mode number at varying rates. Additionally, it is noted that the plate requires more support as the mode number rises.*
KEYWORDS: *Lamination Scheme, Boundary condition, Buckling Load, FEM, Laminated Composite Plate.*

I. INTRODUCTION

Buckling is a characteristic that is shown by composite laminated plates when they are exposed to compressive forces after being laminated. Composites are made up of two or more materials that, when combined, offer properties that would be difficult to get with a single component used on its own. Composites are designed to be utilized in a variety of applications. Additionally, the fibers are responsible for carrying the majority of the weight of these materials. By sheltering fibers from the stresses that are induced by the environment and ensuring that they stay aligned and in the correct position, matrices that have a low modulus and a high elongation provide flexible structural performance. In addition, these matrices enable the fibers to remain in the correct position. By virtue of the composition of the elements, composite materials, which are composed of two or more components, are able to significantly reduce the weight of the structure while yet maintaining a high strength-to-weight ratio. This is made possible by the composite materials' composition. Fiber-reinforced composites are often used in the construction sector, where they are typically fabricated in the form of a lamina, which is a thin sheet. The laminae are the most prevalent kind of material macrounit that may be found throughout the whole material. It is possible to make modifications to the stacking sequence of layers as well as the orientation of fibers inside each lamina in order to get the right degree of strength and stiffness for a particular application. Alterations may be made in order to reach the desired level of strength and stiffness. The composition, distribution, and orientation of the components that make up a composite material are the factors that bring about the unique features of the composite material. These qualities are the result of a one-of-a-kind combination of traits that are brought about by the composite material. It is required to make cutouts for a number of reasons, including the reduction of weight, the improvement of air circulation, and the construction of linkages between components that are located in close proximity to one another. Carbon-fiber reinforced plastic is a composite material that is produced by mixing a variety of carbon fibers with thermosetting resins. This results in the creation of the material. In addition to being lightweight and nonconductive, carbon fiber reinforced plastic, usually referred to as CFRP, is a material that is strengthened with fibers. However, it is also lightweight. It is a material that stands the test of time very well. It is possible to efficiently increase the material's strength and stiffness attributes by stacking a large number of fiber sheets in a variety of orientations. This is a practical method. The finite element approach was used by Parth Bhavsar and his colleagues in order to explore the buckling behavior of glass fiber reinforced polymer (GFRP) when subjected to loads that increased linearly.

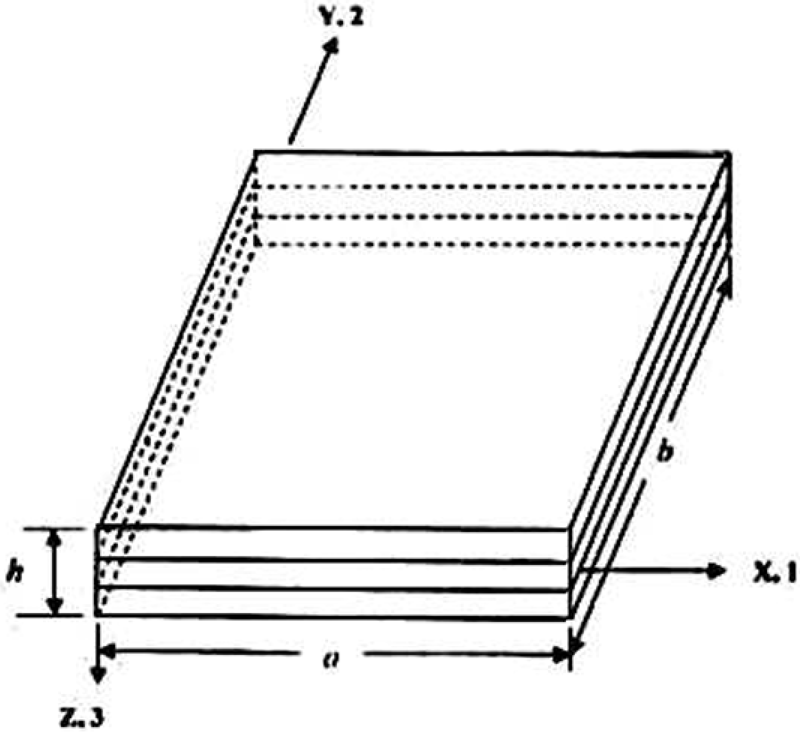

Figure 1: Laminated Composite Plate

Research into the parameters that affect the buckling stress of rectangular plates with an aspect ratio of 1 has focused on a number of different aspects. The buckling stress per unit length of a rectangular plate with circular cut-outs subjected to bi-axial compression was determined by Joshi and colleagues using two-dimensional finite element analysis. To test the buckling variables, one may change the length-to-thickness ratio or move the holes around. Nagendra Singh Gaira and colleagues studied the buckling behavior of laminated rectangular plates in the setting of clamped-free boundary conditions. The buckling load is decreased when cut-outs are present, which is an advantageous outcome. The intended outcome of increasing the aspect ratio is to decrease the buckling load factor. Using a laminated composite cylindrical panel, Hamidreza Allahbakhsh and Ali Dadrasi conducted buckling study to examine the effect of an axial load on the buckling load. A variety of sizes and locations for the elliptical cutout were used in the experiment. The buckling stress on rectangular plates is studied by Container Okutan Baba in relation to various cut-out geometries, length-to-thickness ratios, and ply orientations. Researchers used theoretical and experimental approaches to learn how these factors affected the buckling behavior of E-glass/epoxy composite plates subjected to in-plane compression stress. According to Hsuan-Teh Hu and colleagues' finite element buckling study of composite laminate skew plates under uniaxial compressive loads, the failure criteria and nonlinear in-plane shear significantly affect the skew plates' ultimate loads. The linearized buckling loads, on the other hand, are less severe.

II. FINITE ELEMENT METHOD FOR NUMERICAL ANALYSIS WITH MATERIALS

A simple technique to meet the format requirements for the conference paper. The goal of this study is to establish the buckling load factors of carbon fiber composite plates with square or cylindrical shapes using finite element analysis. ANSYS Version 14.5 is the APDL version. When examining the plate's dimensions, three distinct boundary conditions are taken into account: fixed, clamped, and unclamped situations. The first scenario consists of two levels, while the second scenario is divided into three levels. This may be due to the stacking sequences employed, which were [00/900] and [00/900/00], respectively. To conduct the research, the plate must be perforated with a large number of center holes of equal volume. The center holes may be placed in a number of ways, including square, triangular, circular, and star arrangements. An examination of the buckling load factor's characteristics is now underway.

III. DESCRIPTION OF ELEMENT

This specific task makes use of the SHELL281 element type. The existence of this shell element facilitates the analysis of thin or fairly thick shells. Additionally, it is a great material for simulating sandwich structures and laminated composite coatings because of its versatility. You may utilize this material effectively in applications where there is a lot of strain nonlinearity, linearity, or rotation. There are eight nodes in the element, and there are six degrees of freedom in each of those nodes. All three axes of rotation and translation along the element's internal x, y, and z axes are made possible by these degrees of freedom. Research involving cylindrical plates makes use of the nonlinear element S8R5. This component stands out due to its eight nodes, each of which has five degrees of freedom.

IV. GEOMETRIC MODELLING

Square plates may be 500 mm in size as a starting point. The central hole has an estimated diameter of fifty millimeters. In the case of cylindrical specimens, the nominations might range from L500 to R200. The panel's length is represented by the number after the letter L, and its radius is the number following the letter R. Two millimeters, two and a half millimeters, three millimeters, and three and a half millimeters are the four different thickness options for the plate.

Table 1: Carbon Material Properties

Young's modulus (Pa)	E_{11}= $1.397x10^{11}$	E_{33}= $1.139x10^{11}$
Poisson's ratio	ν_{12}= 0.3236	ν_{13}= 0.3236
Rigidity modulus (Pa)	G_{12}= $4.753x10^{9}$	G_{13}= $4.753x10^{9}$

V. PLATE MODEL OF COMPOSITE LAMINATE

One possible starting point for the length of square plates is 500 millimeters. According to estimates, the diameter of the hole in the middle measures fifty millimeters.There is a possibility that nominations for cylindrical specimens might vary from L500 to R200. The length of the panel is denoted by the number that comes after the letter L, and the radius of the panel is denoted by the numeral that comes after the letter R.

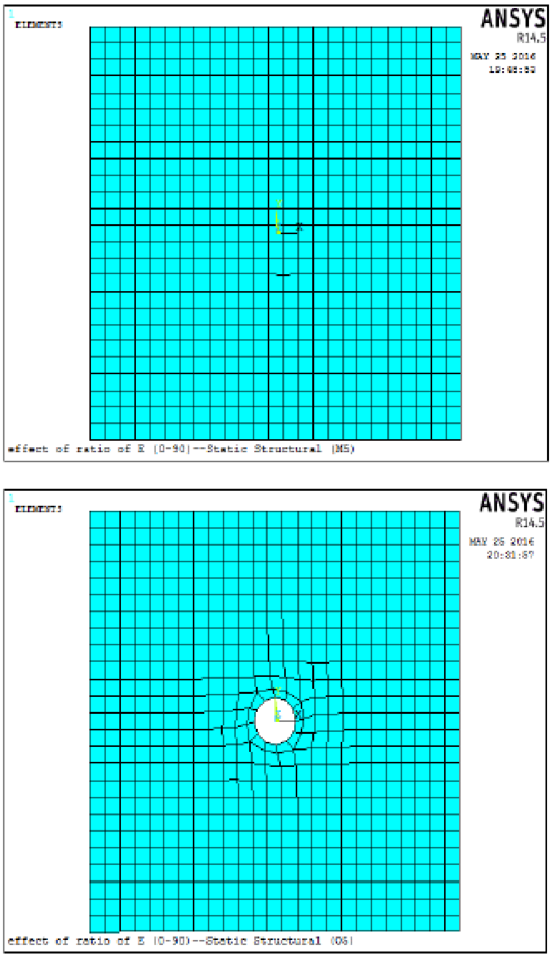

Figure 2 : Model of square plate without and with cut-out

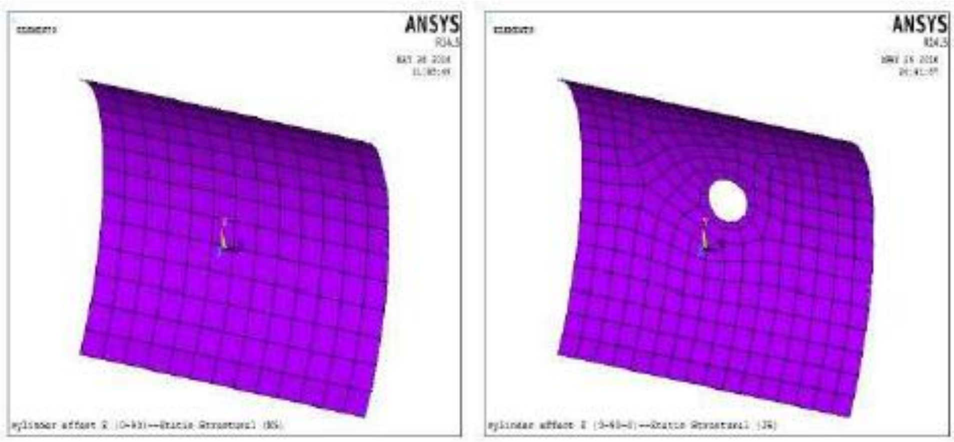

Figure 3: Model of cylindrical plate without and with cut-out

VI. RESULTS AND DISCUSSION

The objective of this section is to explore the influence that different ply orientations of the plate have on the plate when it is exposed to the same boundary condition since that is the aim of this section. This is going to be carried out simultaneously. This particular instance is a condition that is fixed at the border, and it is that condition that is being taken into consideration. There are a variety of ply orientations that are used in this section. These orientations are as follows: (0/0/0), (0/30/0) and (90/0/90). To get further information, kindly refer to the list that is provided below.An examination of both of them is carried out, and a research is conducted to investigate the consequences that the circumstance has brought about.

Analysis is performed on both of them, and an investigation into the consequences of it is carried out.

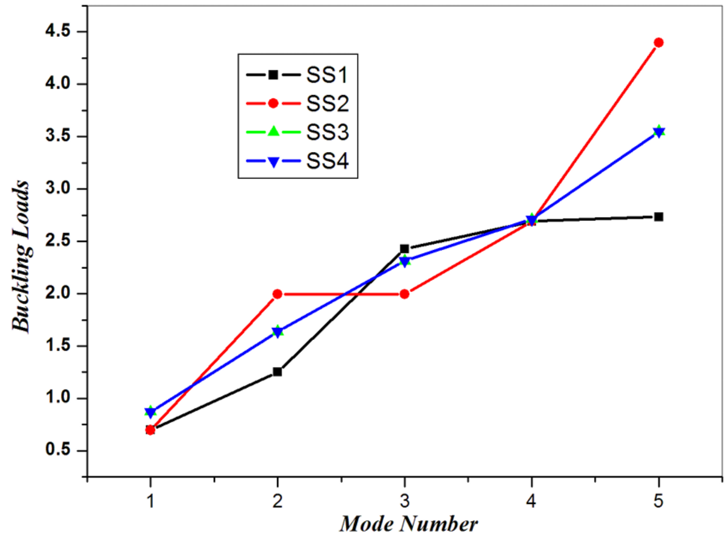

Figure 4 : Effect of lamination scheme for simply supported laminates

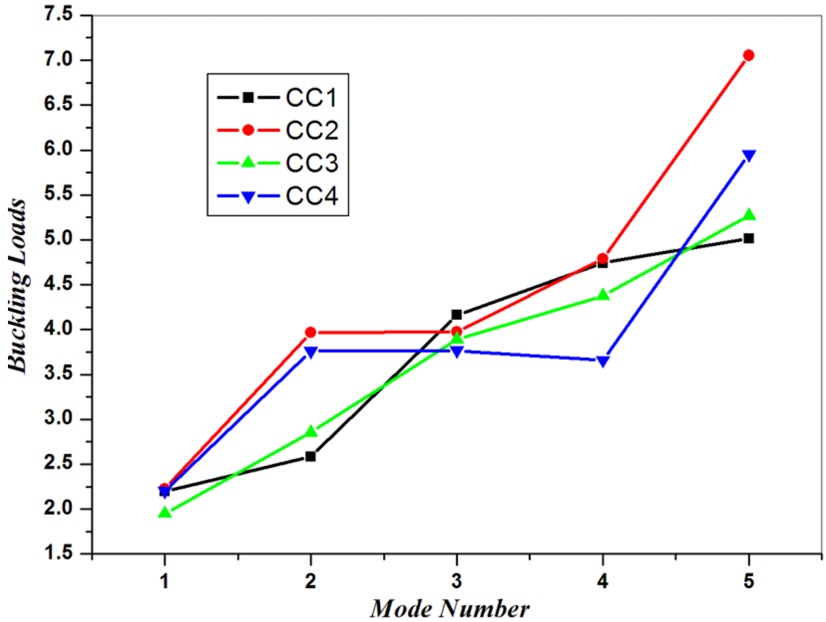

Figure 5 : Effect of lamination scheme for clamped – clamped laminates

The influence of the boundary conditions on the buckling load is shown in Figure 4 and Figure 5, respectively, for a square composite plate and a cylindrical composite plate. According to the findings of this investigation, the laminated plates are examined under three separate border circumstances, each of which displays a unique set of behavioral traits. The boundary conditions that were chosen are clamped, unclamped, and fixed boundary conditions that are applied to the sides of the plates themselves. Composites' boundary conditions have the most significant impact on the buckling load that they experience.

Following an investigation into the relationship between the buckling load and the ply orientation for unclamped, clamped, and fixed boundary conditions, it was discovered that the maximum buckling load for a particular boundary condition occurs at a ply orientation of (0/90/0). This suggests that plates with a greater number of layers have a greater ability to bear buckling loads than plates with fewer thicknesses.

As a result of reducing the L/t ratio, the results demonstrate that the buckling loads of the plates significantly rise under whatever boundary conditions are present. Buckling load is greatest for thicknesses of 3.5 millimeters, and it is least for thicknesses of 2 millimeters.

When the boundary conditions are fixed, the buckling load is at its highest, whereas when the boundary conditions are unclamped, it is at its lowest.

VII. CONCLUSIONS

The goal of this work is to investigate the buckling behavior of laminated composite plates under various boundary circumstances. Keep in mind that laminated composite plates exist in a variety of shapes, width to thickness ratios, cutting patterns, and hole locations. This study might lead to a variety of findings, including the following: A lower L/t ratio leads to a larger buckling load. The cut-out reduces the buckling load. A cutaway minimizes the surface area, lowering the load necessary to buckle and deform the plate. As a result, the buckling load is minimized. The buckling load grows linearly as the number of layers increases. This is because there is a direct relationship between the number of layers and the level of interlayer communication. As a result, attaining the critical buckling load demands a significant amount of load. Similarly, increasing the EL/ET ratio leads to an increase in buckling load. The buckling stress may vary according on the cut-out forms. It has been established that circular cut-outs have the largest buckling stress. The buckling stress is likewise the lowest for equally sized star cuts.

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