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Research Paper

Impact of Various Boundary Conditions on the Buckling Load of the Laminated Composite Plate

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ABSTRACT:
The finite element (FE) approach is used in order to investigate thin rectangular laminated composite plates that are subjected to the biaxial action of in-plane compressive stress. A piece of software that is written in Fortran has been developed. The convergence and validity of the answers were validated by the process of comparing the finite element (FE) solutions for biaxial buckling of thin laminated rectangular plates with other theoretical solutions. In order to quantify the effects of the lamination scheme, aspect ratio, material anisotropy, fiber orientation of layers, reversed lamination scheme, and boundary conditions, novel numerical results are developed for in-plane compressive biaxial buckling. These findings are then used to determine the effects of these factors. It was observed that symmetric laminates are more rigid than anti-symmetric laminates. This comes about as a result of the connection between bending and stretching, which reduces the buckling stresses of symmetric laminates. The buckling load increases in proportion to the aspect ratio, whereas the buckling load decreases in proportion to the modulus ratio. Changing the order in which the laminations are performed will not affect the buckling load in any way. The buckling load increases with the mode number at different rates, and this is dependent on the kind of end support that is being used. In addition, it has been observed that the plate calls for an increased amount of support depending on the mode number.

KEYWORDS: *Boundary condition, Buckling Load, FEM, Laminated Composite Plate.*

I. INTRODUCTION

Buckling is a feature that composite laminated plates exhibit when subjected to compressive stresses after being laminated. Composites are made up of two or more materials that, when combined, provide qualities that are difficult to achieve with a single component employed alone. Composites are intended to be used in a wide range of applications. Furthermore, the fibers support the bulk of the weight of these materials. Matrixes with a low modulus and a high elongation offer flexible structural performance by protecting fibers from environmental pressures while also ensuring that they remain aligned and in the proper location. Furthermore, these matrices allow the fibers to stay in the proper location. Composite materials, which are made up of two or more components, may drastically lower the weight of the construction while retaining a high strength-to-weight ratio. This is achievable due to the composition of the composite components. Fiber-reinforced composites are often employed in the construction industry, where they are generally manufactured in the form of a lamina, a thin sheet. Laminae are the most common kind of material macrounit that may be found throughout the material. Modifications to the layer stacking sequence and fiber orientation inside each lamina may be made to provide the desired level of strength and stiffness for a specific application. Adjustments may be made to get the required amount of strength and stiffness. The composition, distribution, and orientation of the components that comprise a composite material are the elements that determine the composite material's distinctive properties. These characteristics are the outcome of a unique mix of attributes produced by the composite material. Cutouts are necessary for a variety of reasons, including weight reduction, improved air circulation, and the creation of links between components that are near together. Carbon-fiber reinforced plastic is a composite material made by combining various carbon fibers with thermosetting resins. This leads to the formation of the substance. Carbon fiber reinforced plastic, often known as CFRP, is a polymer that is strengthened with fibers. It is lightweight and nonconductive. However, it is also light. It is an extremely durable substance. By stacking a large number of fiber sheets in a variety of orientations, you may effectively improve the material's strength and stiffness. This is a realistic approach. Parth Bhavsar and his colleagues employed the finite element technique to investigate the buckling behavior of glass fiber reinforced polymer (GFRP) under linearly increasing loads.

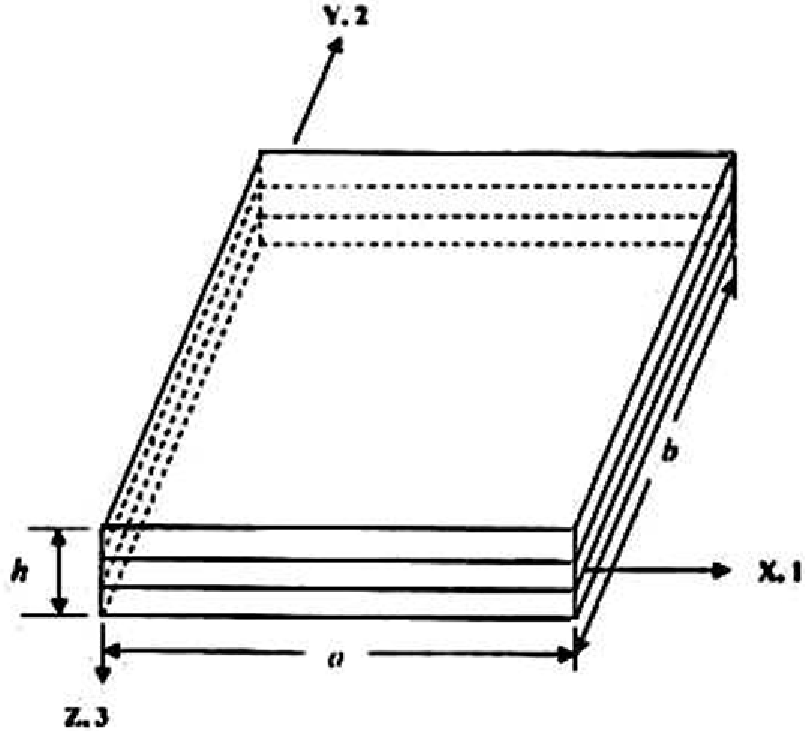

Figure 1: Laminated Composite Plate

A variety of characteristics have been studied to see how they impact the buckling stress of rectangular plates having an aspect ratio of one. Joshi and colleagues used two-dimensional finite element analysis to calculate the buckling stress per unit length of a rectangular plate with circular cutouts under biaxial compression. To test the buckling variables, adjust the length-to-thickness ratio or move the holes around. Nagendra Singh Gaira and colleagues investigated the buckling behavior of laminated rectangular plates under clamped-free boundary circumstances. When cut-outs are present, the buckling load decreases, which is a good thing. The goal of raising the aspect ratio is to reduce the buckling load factor. Hamidreza Allahbakhsh and Ali Dadrasi performed a buckling research on a laminated composite cylindrical panel to investigate the influence of an axial load on buckling load. The experiment included a range of elliptical cutout sizes and positions. Container Okutan Baba investigates the buckling stress on rectangular plates with different cut-out geometries, length-to-thickness ratios, and ply orientations. Researchers utilized theoretical and experimental methods to investigate how these parameters influenced the buckling behavior of E-glass/epoxy composite plates under in-plane compression stress. Hsuan-Teh Hu and colleagues' finite element buckling research of composite laminate skew plates under uniaxial compressive loads found that failure criteria and nonlinear in-plane shear had a substantial impact on the skew plates' ultimate loads. In contrast, linearized buckling loads are less severe.

II. FINITE ELEMENT METHOD FOR NUMERICAL ANALYSIS

A easy way for meeting the conference paper's formatting criteria. This study's purpose is to use finite element analysis to determine the buckling load factors of carbon fiber composite plates with square or cylindrical geometries. ANSYS 14.5 is the APDL version. When assessing the plate's dimensions, three different boundary conditions are considered: fixed, clamped, and unclamped scenarios. The first scenario has two levels, whilst the second has three. This might be owing to the stacking sequences used, [00/900] and [00/900/00], respectively. To perform the investigation, the plate must be perforated with a large number of equal-volume center holes. The center holes may be put in a variety of configurations, including square, triangular, circular, and star patterns. A study of the buckling load factor's properties is now conducted.

III. DESCRIPTION OF ELEMENT

This particular job makes use of the SHELL281 element type. The presence of this shell element aids in the examination of thin or rather thick shells. It is also an excellent material for imitating sandwich structures and laminated composite coatings due to its flexibility. This material may be used successfully in applications that need a high level of strain nonlinearity, linearity, or rotation. The element consists of eight nodes, each with six degrees of freedom. These degrees of freedom allow for rotation and translation along all three of the element's internal axes (x, y, and z). S8R5 is a nonlinear element used in research on cylindrical plates. This component distinguishes out for its eight nodes, each with 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)	$E_{11}=$ $1.397\text{x}10^{11}$	$E_{33}=$ $1.139\text{x}10^{11}$
Poisson's ratio	$\nu_{12}= 0.3236$	$\nu_{13}= 0.3236$
Rigidity modulus (Pa)	$G_{12}=$ $4.753\text{x}10^{9}$	$G_{13}=$ $4.753\text{x}10^{9}$

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.

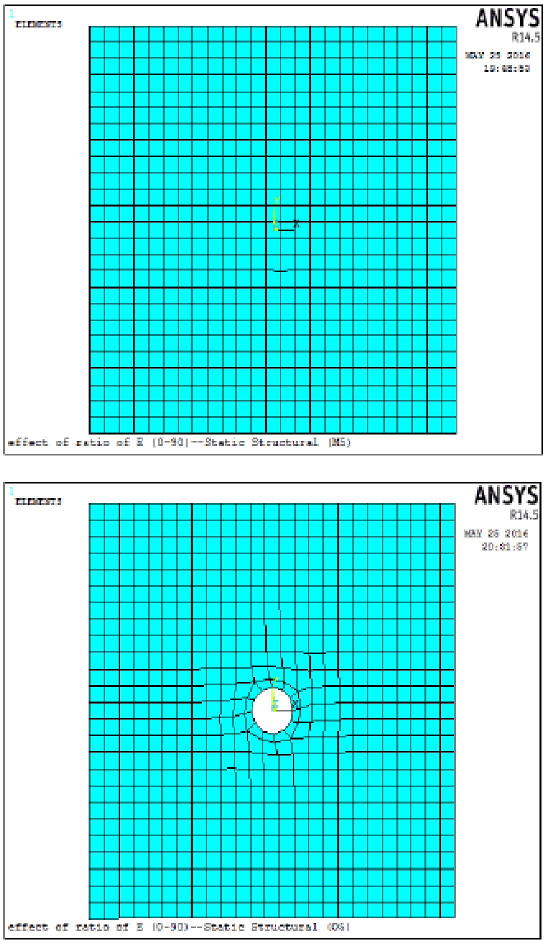

Figure 2 : Model of square plate without and with cut-out

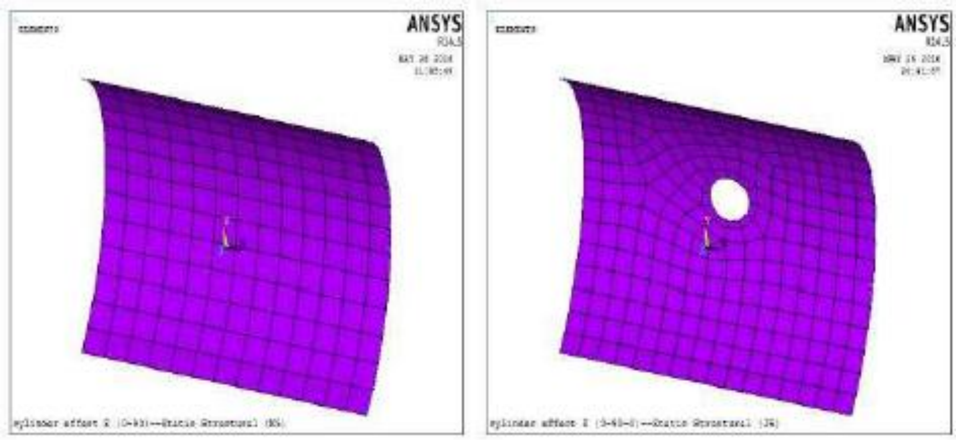

Figure 3: Model of cylindrical plate without and with cut-out

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.

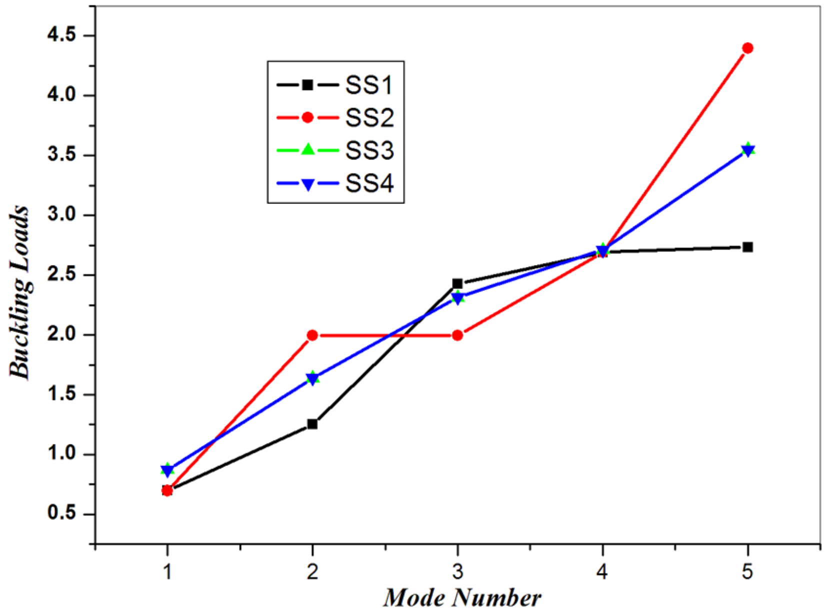

Figure 4 : Effect of lamination scheme for simply supported laminates

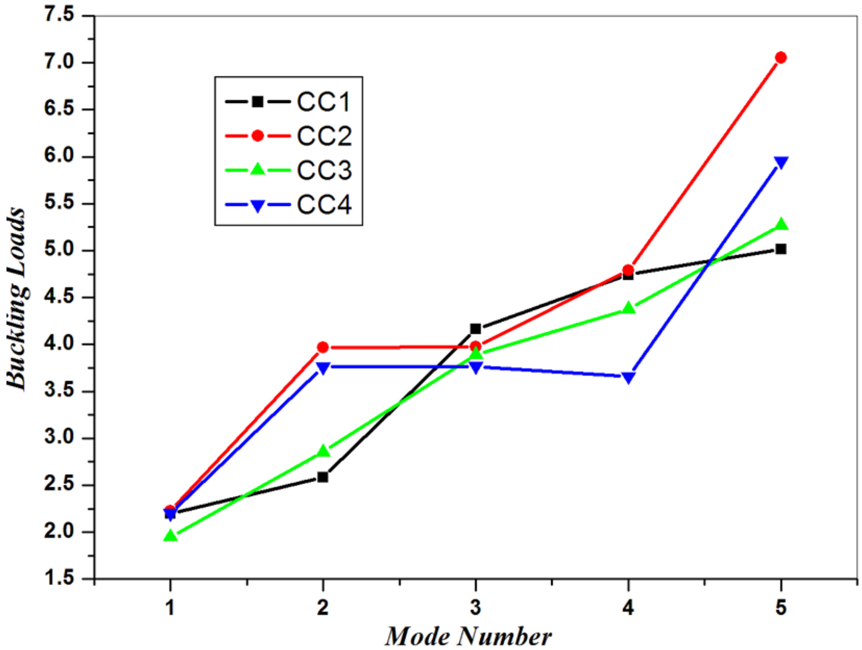

Figure 5 : Effect of lamination scheme for clamped – clamped laminates

In Figure 4 and Figure 5, respectively, the impact of the boundary conditions on the buckling load is shown for a square composite plate and a cylindrical composite plate. Both figures are representative of the composite plate. This inquiry has shown that the laminated plates are investigated under three distinct border conditions, each of which exhibits a different collection of behavioral characteristics. The results of this investigation are presented below. The clamped, unclamped, and fixed boundary conditions that are applied to the sides of the plates themselves are the ones that were selected as the boundary conditions to be applied. The buckling load that composites are subjected to is most significantly influenced by the boundary conditions with which they are surrounded. Following an analysis into the link between the buckling load and the ply orientation for unclamped, clamped, and fixed boundary conditions, it was found that the maximum buckling load for a certain boundary condition occurs at a ply orientation of (0/90/0). This was identified as a result of the inquiry. The conclusion that can be drawn from this is that plates that have a higher number of layers have a better capacity to withstand buckling stresses than plates that have bigger thicknesses. As a consequence of decreasing the L/t ratio, the findings indicate that the buckling loads of the plates dramatically increase regardless of the boundary conditions that are present. A thickness of 3.5 millimeters results in the largest amount of buckling load, while a thickness of 2 millimeters results in the least amount. In situations when the boundary conditions are not clamped, the buckling load is at its lowest, and when the boundary conditions are clamped, it is at its maximum.

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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