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Research Paper

An Effect of Different Boundary conditions of Plate on the Buckling Load of Laminated Composites

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ABSTRACT:
Laminated composite plates are made up of layers of bonded materials that have different chemical compositions and are built in a macroscopic manner. Plates produced from laminated composite material with holes display less stiffness, less inertial resistance, and poorer strength compared to solid plates. Within the scope of this investigation, the optimization and nonlinear behavior of square and cylindrical laminated plates, both with and without cuts, as well as their performance under buckling loads when they are uncut, are the primary areas of attention. Cutouts are required for a variety of reasons, including ventilation, cable attachments, and weight reduction, and they are essential for accomplishing the goal of reducing weight as much as possible. Within the framework of the evaluation process, many aspects are taken into consideration, including the cutting location, the fiber orientation angle, the length-to-thickness ratio, the boundary condition, and Young's Modulus Ratio. The laminated plates that were evaluated were made up of carbon fiber reinforced composites, which are the materials that are being investigated. When compared to plates that do not have any cuts, laminated composite plates that have circular cutouts have a lower buckling load characteristic.
KEYWORDS: *Boundary condition, Buckling Load, FEM, Laminated Composite Plate.*

I. INTRODUCTION

When composite laminated plates are subjected to compressive stresses, they display a feature known as buckling. Composites are made up of two or more materials that, when combined, produce qualities that would be difficult to get with a single component used on its own. For the most part, the weight of these materials is carried by the fibers. Matrices that have a low modulus and a high elongation offer flexible structural performance while also shielding fibers from the stresses that are caused by the environment and ensuring that they remain aligned and in the proper position. Composite materials, which are made up of two or more components, are able to drastically lower the weight of the structure while yet retaining a high strength-to-weight ratio due to the composition of the elements.When used in the construction industry, fiber-reinforced composites often take the form of a lamina, which is a thin sheet. The laminae are the most common kind of material macrounit for the material. In order to achieve the appropriate level of strength and stiffness for a certain application, it is possible to make adjustments to the stacking sequence of layers as well as the orientation of fibers inside each lamina. The distinctive characteristics of a composite material are the consequence of a one-of-a-kind combination of characteristics that are brought about by the composition, distribution, and orientation of the components that make up the composite. Cutouts are necessary for a variety of reasons, including the reduction of weight, the enhancement of air circulation, and the establishment of links between components that are close to one another. Carbon-fiber reinforced plastic is a composite material that is created by combining a number of different kinds of carbon fibers with thermosetting resins. Carbon fiber reinforced plastic, often known as CFRP, is a material that is not only lightweight and nonconductive but also fortified with fibers. It is an extraordinarily long-lasting substance. By stacking a large number of fiber sheets in a variety of orientations, it is feasible to effectively improve the material's strength and stiffness qualities. In order to investigate the buckling behavior of glass fiber reinforced polymer (GFRP) under linearly increasing stresses, Parth Bhavsar and his colleagues used the finite element method.

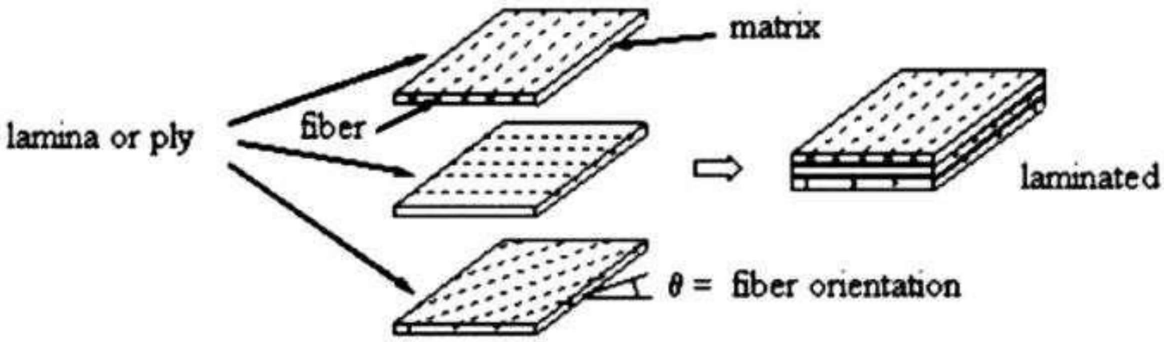

Figure 1: Laminated Composite Plate

A number of elements have been investigated by researchers in order to determine the influence that these factors have on the buckling stress of rectangular plates that have an aspect ratio of 1. Two-dimensional finite element analysis was used by Joshi and colleagues in order to determine the buckling stress per unit length of a rectangular plate that had circular cut-outs while it was subjected to bi-axial compression. Altering the ratio of length to thickness and the positioning of the holes are two methods that may be used to evaluate the buckling variables. In the context of clamped-free boundary conditions, Nagendra Singh Gaira and his colleagues investigated the buckling behavior of laminated rectangular plates. In the presence of cut-outs, the buckling load is reduced, which is a positive consequence. Increasing the aspect ratio will result in a reduction in the buckling load factor, which is the desired consequence. In order to investigate the impact that an axial load has on the buckling load of a laminated composite cylindrical panel, Hamidreza Allahbakhsh and Ali Dadrasi carried out a buckling research on the panel. The investigation included an elliptical cut-out that was constructed in a number of different sizes and places. The research conducted by Container Okutan Baba investigates the ways in which different cut-out geometries, length-to-thickness ratios, and ply orientations affect the buckling stress that is imposed on rectangular plates.For the purpose of determining the consequences of these influences on the buckling behavior of E-glass/epoxy composite plates that were exposed to in-plane compression stress, the researchers used both theoretical and experimental methods. In their finite element buckling analysis of composite laminate skew plates subjected to uniaxial compressive loads, Hsuan-Teh Hu and colleagues discovered that the failure criterion and nonlinear in-plane shear have a significant impact on the ultimate loads of the skew plates. This is in contrast to the linearized buckling loads, which have a smaller impact.

1. Finite Element Method for Numerical Analysis with Materials

A strategy that is straightforward in order to fulfill the criteria of the format for the conference paper Through the use of finite element analysis, the purpose of this work is to determine the buckling load factors of carbon fiber composite plates that are either square or cylindrical in shape. Version 14.5 of ANSYS is the APDL version. There are three unique boundary conditions that are considered while analyzing the dimensions of the plate, which are L x t: fixed, clamped, and unclamped circumstances. The first scenario is comprised of two levels, whilst the second scenario is further broken down into three levels. This may be attributed to the stacking sequences that were used, which were [$0^0/90^0$] and [$0^0/90^0/0^0$], respectively.It is necessary to perforate the plate with a large number of center holes of the same volume in order to carry out the study. The center holes may be arranged in a variety of layouts, including square, triangular, circular, or star configurations. Regarding the properties of the buckling load factor, an investigation is now being carried out.

2. Description of Element

For this particular work, the SHELL281 element type is used. The investigation of shells that are either very thin or somewhat thick is made easier by the presence of this shell element. Furthermore, due to the fact that it may be used in a variety of ways, it is an excellent material for modeling laminated composite coatings and sandwich structures. Applications that are characterized by considerable strain nonlinearity, linearity, or rotation are excellent candidates for the use of this material with great success. The element is composed of eight nodes, and each of those nodes has six degrees of freedom. These degrees of freedom allow for rotation around the three axes as well as translations along the x, y, and z axes that are included inside the element. When doing research with cylindrical plates, the nonlinear element S8R5 is used. This element is distinguished by having eight nodes and five degrees of freedom for each node.

3. Geometric Modelling

One possible starting point for the size 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. In terms of thickness, the plate is offered in four distinct dimensions: two millimeters, two and a half millimeters, three millimeters, and three and a half millimeters.

Table 1: Properties of carbon material

Young's modulus (Pa)	E_{11}= $1.397\text{x}10^{11}$	E_{33}= $1.139\text{x}10^{11}$
Poisson's ratio	ν_{12}= 0.3236	ν_{13}= 0.3236
Rigidity modulus (Pa)	G_{12}= $4.753\text{x}10^{9}$	G_{13}= $4.753\text{x}10^{9}$

4. 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.

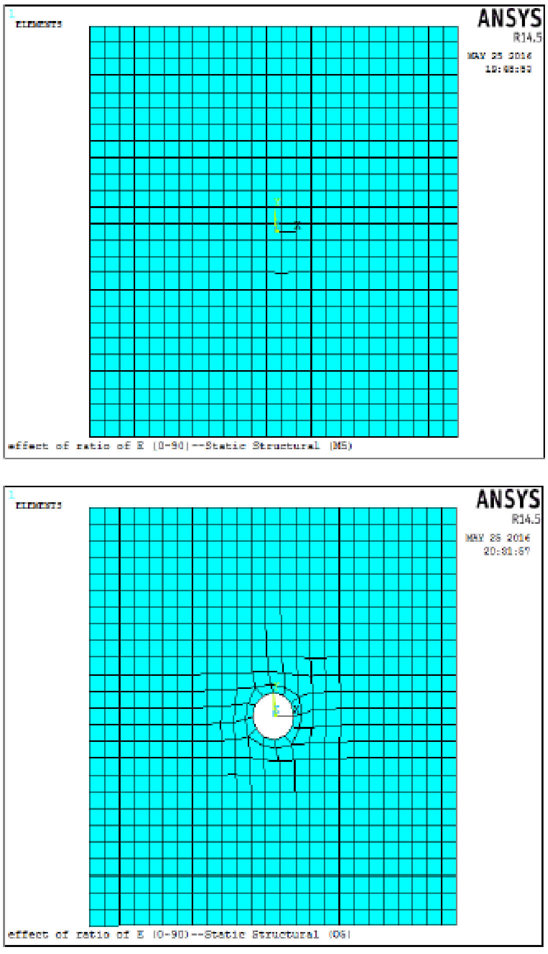

Figure 2 : Model of square plate without and with cut-out

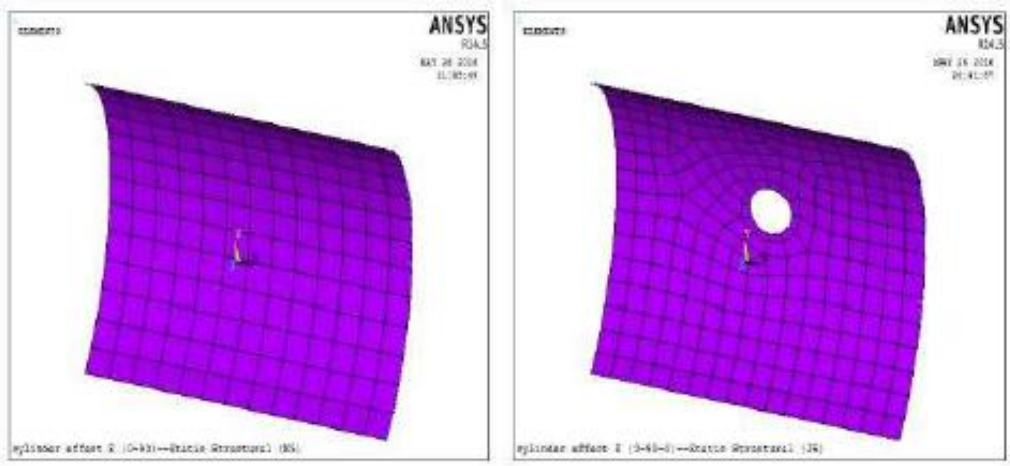

Figure 3: Model of cylindrical plate without and with cut-out

II. 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), (0/45/0), (0/90/0), (90/90/90), 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.

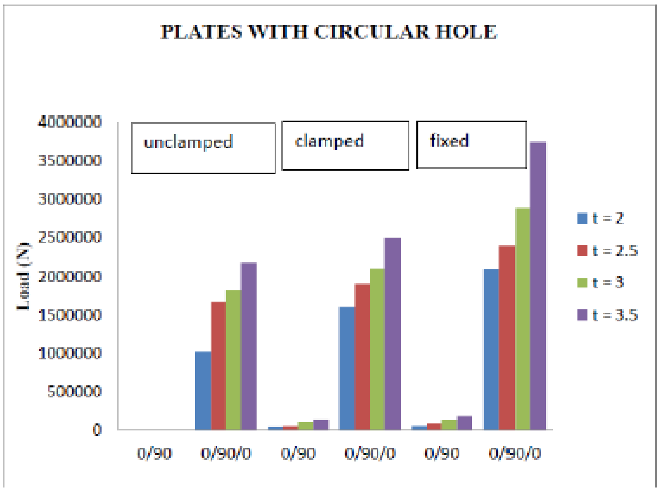

Figure 4 : Comparison graph of square plate with holes

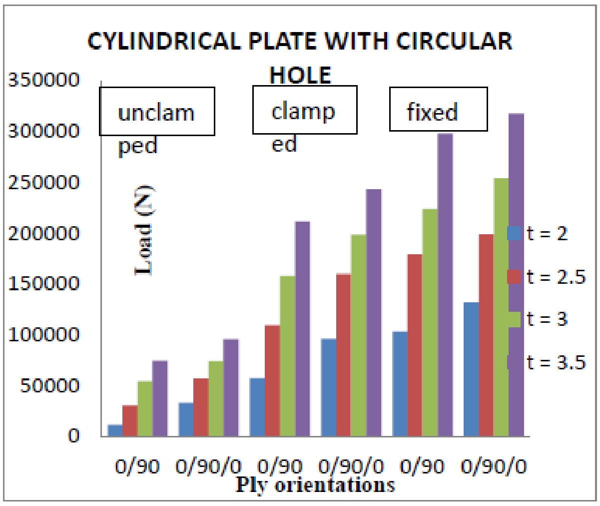

Figure 5 : Comparison graph of cylindrical plate with holes

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.

III. CONCLUSIONS

The purpose of this study is to examine the buckling behavior of laminated composite plates subjected to different boundary conditions.

Keep in mind that the laminated composite plates come in a wide range of forms, with varying width to thickness ratios, cutout patterns, and hole placements.Many conclusions may be derived from this research, some of which are as follows: A smaller L/t ratio results in a higher buckling load. The buckling load is reduced due to the presence of cut-out. The surface area decreases due to a cutout, which in turn reduces the load required to buckle the plate and deform its shape. As a consequence, the buckling load is reduced. With an increasing number of layers, the buckling load increases linearly. This is because there is a direct correlation between the increasing number of layers and the increasing degree of interlayer communication. Consequently, reaching the critical buckling load requires a substantial amount of load. Similarly, when the EL/ET ratio increases, the buckling load also increases. Depending on the cut-out shapes, the buckling load might be different. It has been determined that the buckling load is maximum for circular cut-outs. The buckling load is also the absolute minimum for identically sized star cuts.

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