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Research Paper

Effect of Different Ply Orientations of Plate on Buckling Load of Laminated Composites

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ABSTRACT:
Layers of bonded materials with diverse chemical compositions that are mixed macroscopically make up laminated composite plates. Laminated composite plates with holes in them are weaker, less rigid, and less inertia-resistant than those without. Square and cylindrical laminated plates with and without cuts, as well as their optimization and nonlinear behavior under buckling loads, are studied. In order to reduce weight, cutouts are required for a variety of reasons, including ventilation, cable attachments, and weight reduction. Details such as the position of the cutout, the angle of the fiber orientation, the ratio of length to thickness, the boundary condition, and the Young's Modulus Ratio are assessed. Carbon fiber reinforced composites are the material types of the laminated plates that were examined. The buckling load is lower in laminated composite plates with circular cutouts compared to plates without the cutouts.

KEYWORDS: *Buckling Analysis, Finite Element Method, Laminated Composite Plate, Ply Orientation.*

I. INTRODUCTION

Buckling is a characteristic that composite laminated plates experience when compressed. Composites include two or more materials that, when combined, have characteristics that would have been impossible to get with just one of those materials. The fibers take the brunt of the weight in these types of materials. Matrixes with low modulus and high elongation allow structures to be flexible, while also protecting fibers from environmental stresses and maintaining their place. Composed of two or more components, a composite material provides a substantial reduction in structural weight while maintaining high strength.

A thin layer, or lamina, is the standard constructional shape for fiber-reinforced composites. Material macrounits are called laminae. To attain the strength and stiffness needed for a particular task, the stacking order of the layers and the orientation of the fibers in each lamina may be customized. The uncommon mix of qualities brought about by the composition, distribution, and orientation of the components that make up a composite is what gives the material its properties. For several reasons, including but not limited to reducing weight, allowing air to circulate, and connecting to other units, cutouts are required. Several types of carbon fibers and thermosetting resins come together to form carbon-fiber reinforced plastic, a composite material. Lightweight, nonconductive, and reinforced with fibers, CFRP is an exceptionally robust plastic. It is also possible to efficiently increase the material's strength and stiffness properties by stacking numerous fiber layers with various preferred orientations. The buckling behavior of glass fiber reinforced polymer (GFRP) exposed to linearly variable loading was studied by Parth Bhavsar et al. [1] using the finite element approach.

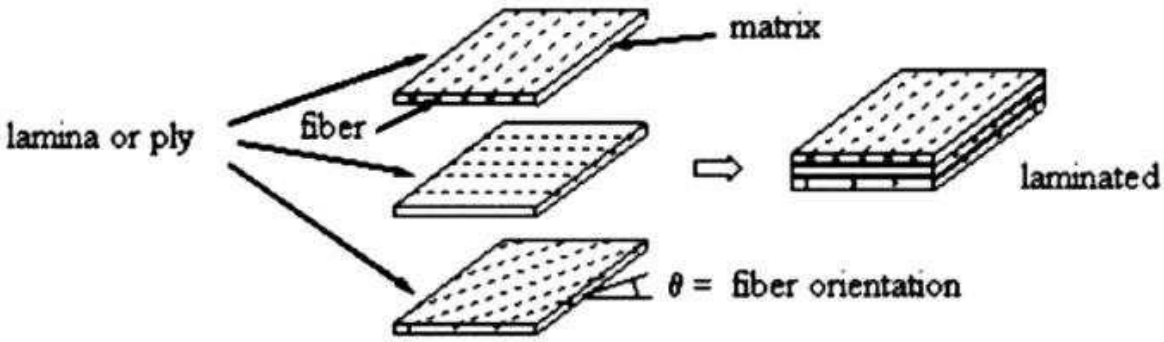

Figure 1: Laminated Composite Plate

Researchers have looked at how different factors affect the buckling stress of rectangular plates with aspect ratios of 1. To find the buckling load per unit length in a rectangular plate with circular cut-outs subjected to bi-axial compression, Joshi et al. [2] used 2D finite element analysis. Altering the length-to-thickness ratio and the placement of the holes allows one to assess the buckling variables. The buckling response of laminated rectangular plates with clamped-free boundary conditions was examined by Nagendra Singh Gaira et al. [3]. Note that the buckling load is reduced by the presence of cut-out. A lower buckling load factor is achieved when the aspect ratio increases. In order to study the effect of an axial load on the buckling load of a laminated composite cylindrical panel with an elliptical cut-out of varying sizes and positions, Hamidreza Allahbakhsh and Ali Dadrasi [4] conducted a buckling analysis. Bucket Okutan Baba [5] investigates how different cut-out shapes, length/thickness ratios, and ply orientations affect the buckling stress on rectangular plates.
To determine these impacts on the buckling behavior of E-glass/epoxy composite plates subjected to an in-plane compression force, researchers used both numerical and experimental methods. In their finite element buckling analysis of composite laminate skew plates subjected to uniaxial compressive loads, Hsuan-Teh Hu et al. [6] found that, in comparison to the skew plates' linearized buckling loads, the failure criterion and nonlinear in-plane shear significantly impact the composite laminate skew plates' ultimate loads.

1. Numerical Analysis Using Finite Element Method and Material

A simple approach to meeting the requirements of the conference paper format The goal of this project is to use finite element analysis to determine the buckling load factors of square and cylindrical carbon fiber composite plates. It is ANSYS 14.5 APDL. With three distinct boundary conditions—fixed, clamped, and unclamped—the plate's dimensions are L x t. The number of layers is two in the first case and three in the second, since the stacking sequence used is [$0^0/90^0$] and [$0^0/90^0/0^0$] correspondingly.

To conduct the study, several identical-area center holes are punched into the plate. Central holes may be either round, square, triangular, or star shaped. The buckling load factor's nature is investigated.

2. Element Description

The SHELL281 element type is being used in this investigation. You may use this shell element to study shells that are either very thin or somewhat thick. Its layered uses also make it useful for modeling sandwich constructions and laminated composite shells. Applications involving high strain nonlinearity, linearity, or rotation are ideal for it. At each of the element's eight nodes, there are six degrees of freedom, allowing for rotation around these three axes as well as translations along the x, y, and z axes. Cylindrical plate studies make use of the eight-node nonlinear element S8R5, which has five degrees of freedom per node.

3. Geometric Modelling

Square plates may have any length from 500 mm onwards. We assume that the diameter of the center hole is 50 mm.Nominations for cylindrical specimens range from L500 to R200. The panel's length is represented by the number after L, while its radius is shown by the number following R. The plate is available in four different thicknesses: 2mm, 2.5mm, 3mm, and 3.5mm.

Table 1: PROPERTIES OF CARBON MATERIAL

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}= $4.753x10^{9}$

4. Model of Carbon Composite Plate

Square plates may have any length from 500 mm onwards. We assume that the diameter of the center hole is 50 mm.Nominations for cylindrical specimens range from L500 to R200. The panel's length is represented by the number after L, while its radius is shown by the number following R.

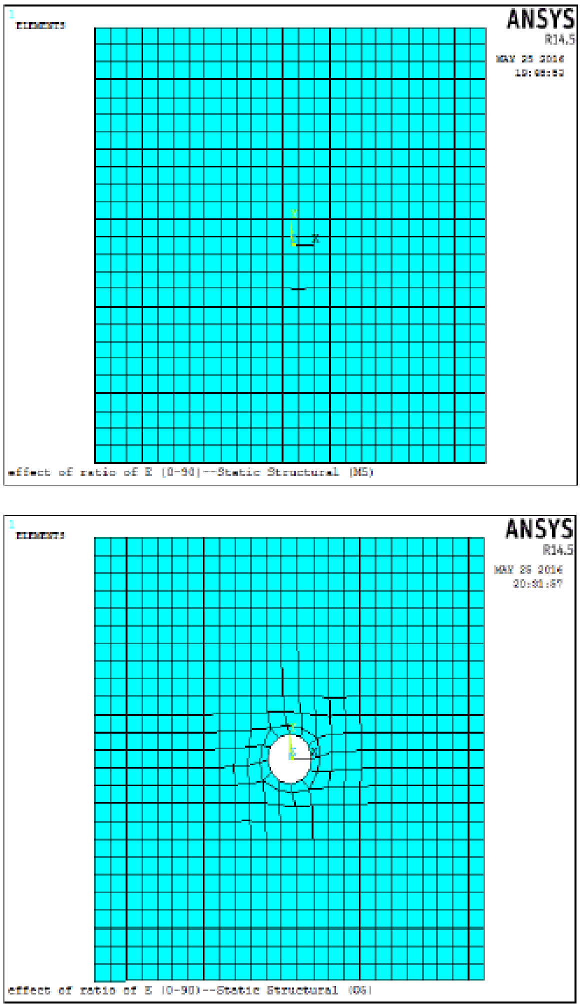

Figure 2 : Model of square plate without and with cut-out

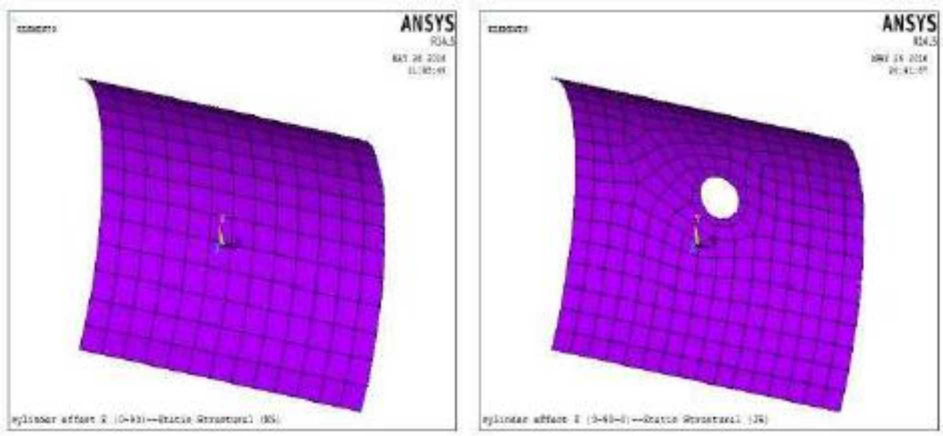

Figure 3: Model of cylindrical plate without and with cut-out

II. RESULTS AND DISCUSSION

The purpose of this section is to investigate the impact that varying ply orientations of the plate have when subjected to the same boundary condition. The condition that is being considered here is a fixed border condition. The following are the many ply orientations that are used in this section: (0/0/0), (0/30/0), (0/45/0), (0/90/0), (90/90/90), and (90/0/90).

Both of these are analyzed, and the repercussions of it are investigated.

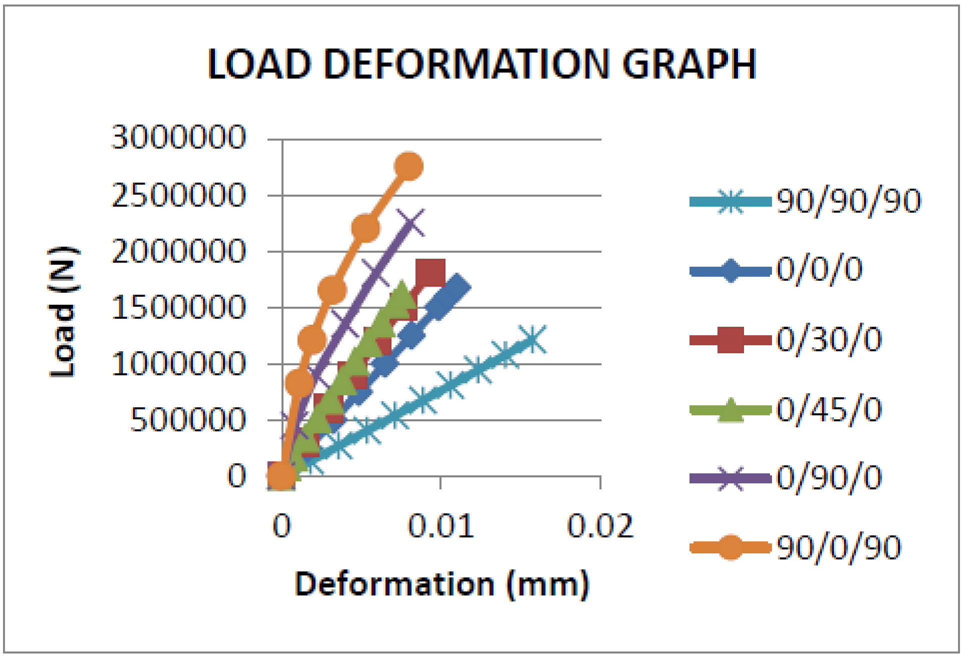

Figure 4 : Buckling load deformation graph of plates with ply orientations

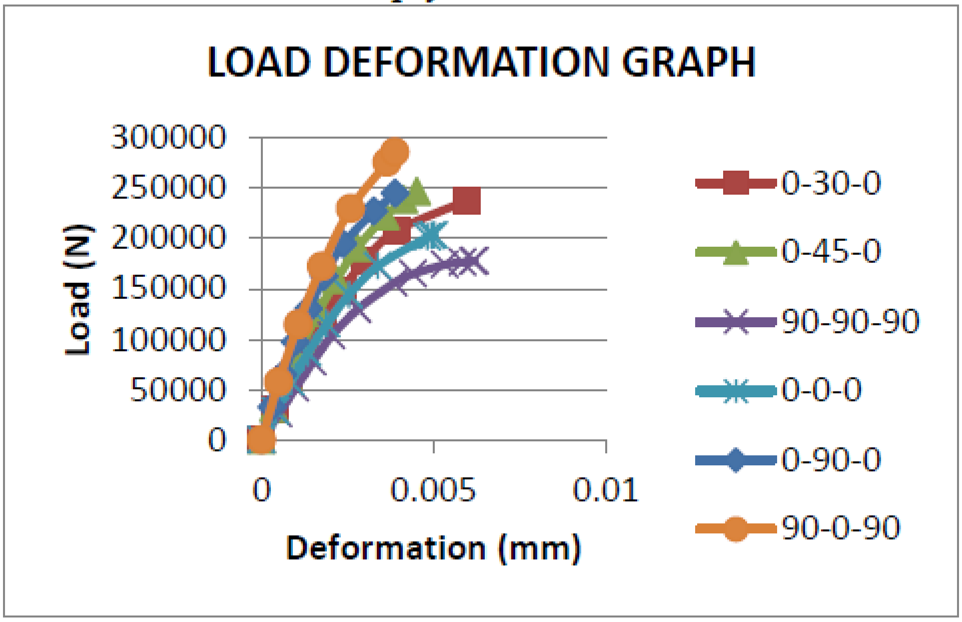

Figure 5 : Buckling load deformation graph of cylindrical plates with ply orientations

In light of the fact that it is generally accepted that the maximum load bearing capacity is for the fixed boundary condition, the fixed condition is being used here as the border. Within the scope of this section, these criteria are applied to both square and cylindrical laminated plates. Figures 4 and 5 depict the load deformation graph of plates that have ply orientations that vary from one another. With the help of this graph, we can get a good concept of how the buckling effect of plates under loads works. In comparison to the other ply angles, the buckling load that is shown by the (90/0/90) ply angle represents the largest. In terms of buckling load bearing ply orientation, the lowest possible value is (90/90/90). Specifically, we conducted our research on a laminated composite plate that had a center circular cut-out feature. This is due to the fact that our research, which was presented in the previous section, reveals that a square laminated composite plate with a center circular cut-out has a favorable buckling load effect under cut-out plates.

III. CONCLUSIONS

Within the scope of this investigation, the buckling response of laminated composite plates with varying boundary conditions is investigated.

It is important to take into consideration that the laminated composite plates have a variety of aspect ratios, shifting width to thickness ratios, cut out shapes, and different locations for holes.

There are many implications that may be drawn from the current study, including the following: The buckling load rises as the L/t ratio lowers. The presence of cut-out results in a reduction in the buckle load. When there is a cut-out present, the surface area lowers, which results in a reduction in the load that is necessary to buckle the plate and cause it to distort its shape. This results in a reduction in the buckling load. The buckling load rises in proportion to the number of layers, as the number of layers grows. The reason for this is because as the number of layers rises, the interaction between each layer also increases. As a result, a significant amount of load is necessary in order to achieve the critical buckling load. The buckling load likewise rises in proportion to the increase in the EL/ET ratio. The amount of load that is buckling varies when the cut-out forms vary as well. In the case of circular cut-outs, the buckling load is found to be the highest possible value. In addition, the buckling load is the lowest possible value for star cutouts of the same dimensions.

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