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Examination of Buckling Load In Laminated Composite Plates with Diverse Cutout Geometries for Optimization

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Abstract-Laminated composite materials are formed by fusing layers of at least two separate materials, functioning as a single entity. Lamination may emphasize attributes like as strength, stiffness, lightweight, corrosion and wear resistance, and acoustic insulation, among others. While cuts are inevitable in structures, the resultant gaps, when required, lead to a decrease in strength and stiffness. This work uses numerical methods to analyse the critical buckling stress of a laminated composite plate with cutouts by modifying the geometries of the cutouts in relation to the laminate's optimum fiber orientation. The buckling load-bearing capacity of laminated composite plates with square and rectangular cutouts is inferior to that of plates with circular cutouts. The arrangement of fiber orientations 0/90/15/-15/15/-15/0/90 combined with circular cutting yielded the maximum buckling stress. The buckling load increases with the elevation of the fiber angle in the inner layers.

Keywords: FE Method, Buckling Load, Laminated Composite Plate, Fibre Orientation, Cutout Geometries.

1. INTRODUCTION

A composite material is made up of two or more parts. It is very strong and has a great stiffness-to-weight ratio, which means it can make constructions much lighter. Laminated composite materials are made up of laminae that are reinforced with fibers and have different characteristics. It is thought that each lamina acts as a continuum, which means that there are no empty spaces, cavities, internal delaminations, or material flaws, and it behaves as a linear hyperelastic material. Some of the properties that may be improved by making composite materials include strength, stiffness, resistance to corrosion, resistance to wear, weight, and behavior that changes with temperature.

The laminates can exhibit symmetry, anti-symmetry, or unsymmetry. They are also referred to as crossply or angle-ply based on the fiber orientations of laminae. When the fiber orientation in a lamina is at 0° or 90°, it is referred to as cross-ply, whereas any other fiber orientations are classified as angle-ply.

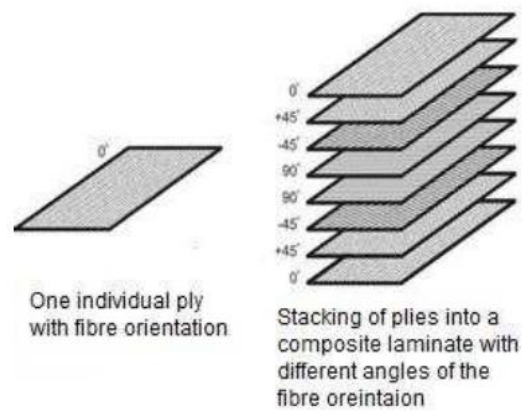

Figure 1. Laminated Composite Material

Cutouts are an important part of buildings. In real life, cutouts may make things weaker, less rigid, and less resistant to change. Cutouts are necessary for many types of civil, mechanical, and aeronautical constructions. Cutouts are used in parts of airplanes to make them lighter, make it easier for fuel and electrical lines to run, and change the resonance frequencies of the structures. Doors and windows are necessary for getting to and fixing the inside parts of an airplane. Cutouts in the bottom plate are necessary for constructions that are meant to hold liquids so that the liquid may flow freely. Cutouts are also needed for ventilation reasons.

This research looks at how cutout shapes and fiber orientation affect the buckling analysis of glass/epoxy laminated composite plates. The plate is constructed of glass to make it stronger, and the matrix is built of Araldite LY 556 as the epoxy resin and Aradur HY 951 as the hardener. Here, glass fibers that go in both directions are used. Most fabric structures like bidirectional tapes better than straight unidirectional ones. When it comes to aerospace constructions, tightly woven textiles are frequently the best choice since they help minimize weight, make resin voids smaller, and make sure that the fibers are properly oriented throughout the manufacturing process. In structural uses, the textiles used have fibers or strands that keep their weight or yield the same in both the longitudinal (warp) and transverse (fill) orientations. Figure 2.

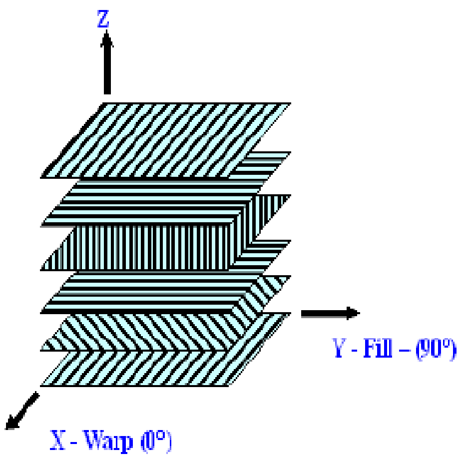

Figure 2. Schematic Representation of Woven Fabric

Through the use of finite element software, more especially ANSYS, this investigation investigates the buckling analysis of laminated composite plates.

2. FINITE ELEMENT ANALYSIS

A composite plate made of glass and epoxy, measuring 250 mm in both length and width, was chosen for the investigation. The thickness of each layer measured 0.3 mm. The characteristics of materials were determined through laboratory testing of the fibers. Table 1 presents the properties of the materials used in the fibres. Cutouts measuring 1964 mm2 are incorporated at the center.

Table 1 Material Properties of Fibre

Material Property	Value
Density	1.2 g/cm^3
Modulus of Elasticity	10GPa
Poisons Ratio	0.12

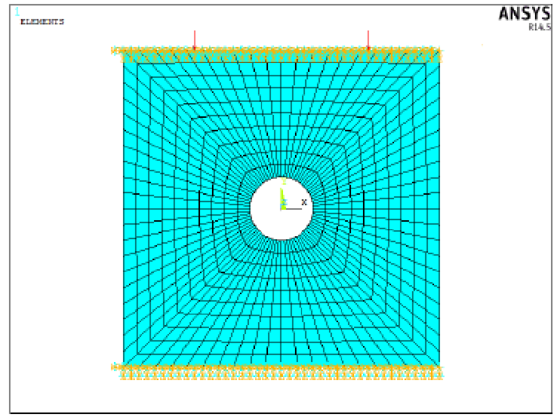

Figure 3. Boundary Condition of Plate with Circular Cutout

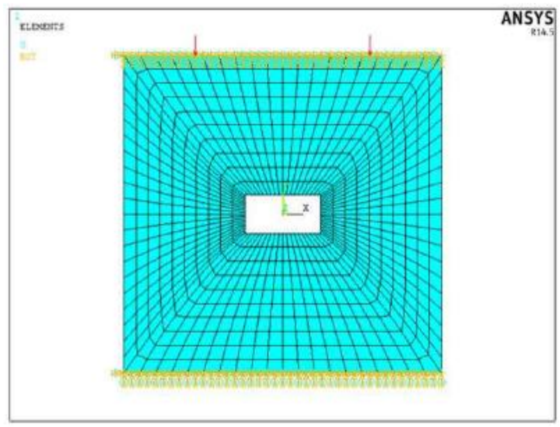

Figure 4. Boundary Condition of Plate with Rectangular Cutout

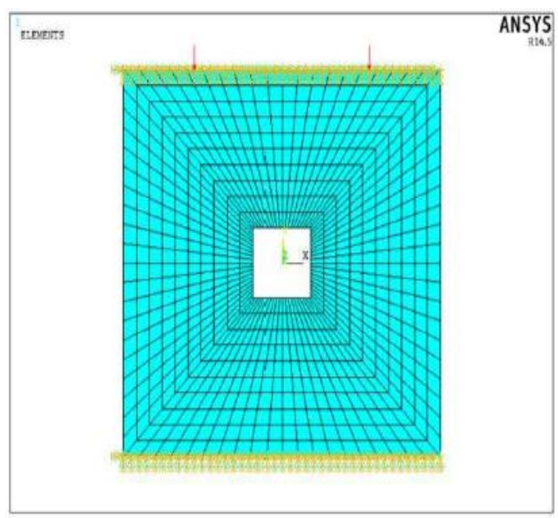

Figure 5. Boundary Condition of Plate with Square Cutout

The buckling study of the plate was carried out with the assistance of ANSYS 14.5, with shell 181 serving as the element type. A variety of cutout shapes and fiber orientations were included into the design of the plates. Utilizing cutout shapes in circular, rectangular, and square configurations, optimized fiber-oriented laminated plates are comprised of these shapes. In order to establish boundary conditions, the top and lower parts of the plate were limited. After the material parameters were assigned, a pressure load of one Newton per square millimeter was applied for the linear buckling analysis.

3. RESULTS OF THE BUCKLING ANALYSIS

3.1 Optimization of Fibre Orientation

Through the use of the Eigen value buckling analysis that is made available by the program, it is feasible to compute the theoretical buckling load of an ideal elastic structure. In addition to this, it provides the eigen value for the restrictions and loads of the system, which is a substantial contribution. In order to accomplish the objective of optimizing the orientation of the fibers, ten different combinations of fiber angle with circular cutout were used over the duration of the study. An explanation of the findings that were discovered as a consequence of the investigation is provided in Table 2.

Table 2 : Buckling Load Values of Different Fibre Orientations with Circular Cutout

Sl. No.	Fibre Orientation (in degrees)	Buckling Load (kN)
1	30/-30/30/-30/30/-30/30/-30	2.943
2	15/-15/15/-15/15/-15/15/-15	4.307
3	60/-60/60/-60/60/-60/60/-60	2.94
4	0/90/30/-30/30/-30/0/90	4.712
5	0/90/15/-15/15/-15/0/90	5.141
6	0/90/60/-60/60/-60/0/90	4.712
7	15/30/15/30/0/90/0/90	3.554
8	45/90/45/90/0/90/0/90	3.96
9	0/90/15/30/15/30/0/90	4.356
10	0/90/45/90/45/90/0/90	4.771

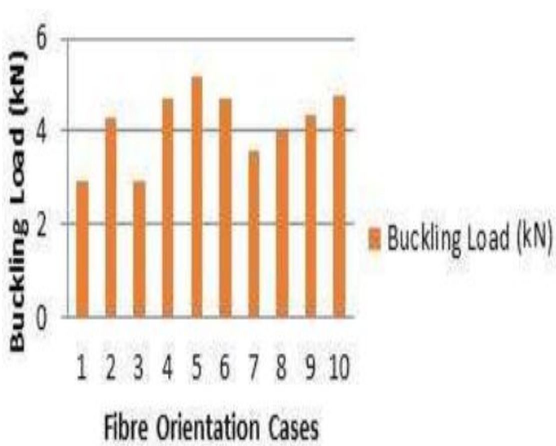

Figure 6. Graph showing the Buckling Load versus Fibre Orientation

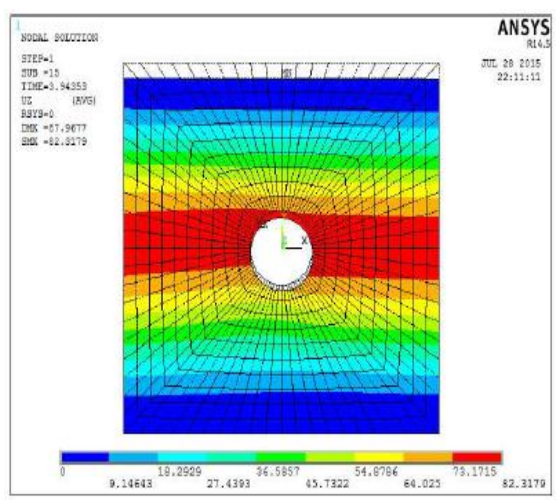

Figure 7. Lateral Deflection of Optimized Laminated Composite Plate

3.2 Optimization for shape of Cutout

The buckling study was carried out with both rectangular and square cutouts, and the fiber orientation was particularly modified. This was done in order to get a better optimization of the cutout shape of the laminated composite plate. The best fiber-oriented laminated composite plate that did not have any cuts was found to have a buckling load of 6.9 kN. This loading was judged to be accessible for the plate.

Table 3 : Buckling Load Values for Different Cutouts with Optimized Fibre Orientation

Cutout Shape	Buckling Load (kN)	% Reduction in Buckling Load due to Cutout
Plate with Circular Cutout (PWCC)	5.141	25.5
Plate with Rectangular Cutout (PWRC)	4.58	33
Plate with Square Cutout (PWSC)	4.835	30

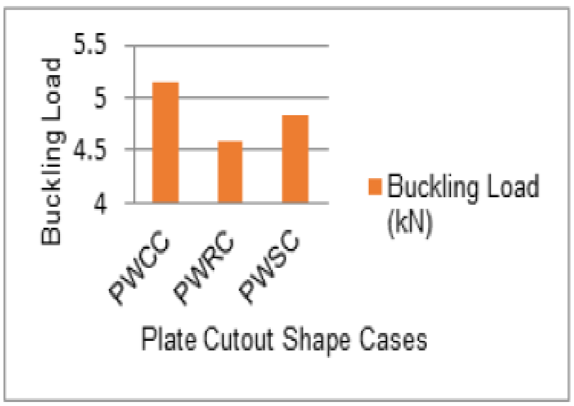

Figure 8. Graph Showing Variation of Buckling Load versus Different Cutouts

4. CONCLUSION

In order to work as a cohesive unit, laminated composite materials are made up of layers that have different qualities and are bonded together. After conducting an investigation using the numerical approach, which investigates a variety of cutout shapes and fiber orientations, the following findings have been uncovered. Increasing the fiber angle in the inner layers results in a reduction in the buckling load value. In order to establish the maximum buckling load, a laminated composite plate that was exposed to a circular and rectangular cutouts was under investigation. The combination of a circular cutout and a fiber orientation of 0/90/15/-15/15/-15/0/90 resulted in the greatest buckling load combination that was achieved. The circular cutout leads to a decrease in buckling load that is 25.5% lower than square cutout.

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