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Optimization of Different Shape of Cutouts by Buckling Analysis of Laminated Composite Plate

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Abstract: *Laminated composite materials consist of layers of at least two different materials that are bonded together to act as a single unit. The properties that can be emphasized by lamination are strength, stiffness, low weight, corrosion resistance, wear resistance, acoustical insulation etc. Cutouts are inevitable in structures, but reduce the strength and stiffness due to the openings provided when required. This paper compares the critical buckling load of the laminated composite plate with cutout by changing the cutout shapes of the optimized fibre orientation of the laminate by numerical methods. Laminated composite plate with rectangular and square cutout shows a decrease in buckling load carrying capacity than plates with circular cutouts. The maximum buckling load combination was obtained with fibre orientation 0/90/15/-15/15/-15/0/90 with circular cutout. With increase in fibre angle in the inner layers, the buckling load increases.*
Keywords - *Buckling Analysis, Cutouts, Fibre Orientation, Finite Element, Laminated Composite Plate*

I. Introduction

A composite material consists of two or more materials and offers a significant weight saving in structures in the view of high strength and high stiffness to weight ratio respectively. Laminated composite materials are made of fiber reinforced lamina of different properties. It is assumed that each lamina is a continuum (i.e., no empty spaces, voids, internal delaminations, or material defects exist) and it behaves as a linear hyperelastic material. The properties that can be improved by forming composite materials include strength, stiffness, corrosion resistance, wear resistance, weight, temperature dependent behavior etc.

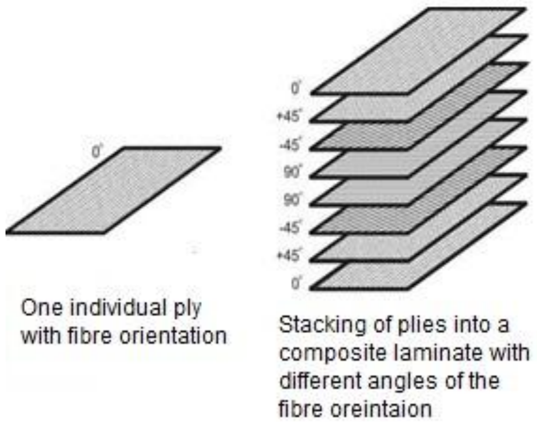

Fig.1. Laminated Composite Material

The laminates may be symmetric or anti-symmetric or unsymmetric. They are also reffered to as cross-ply or angle-ply depending on the fiber orientations of lamiae. If the fiber orientation in a laminae are 0^0 or 90^0, it is called cross-ply and for any other fiber orientations, it is known as angle-ply.

Cutouts are inevitable in structures. In actual applications, strength, stiffness and inertia may be reduced due to cutouts. Cutouts are required in many aeronautical, mechanical and civil structures. In aircrafts components (such as wing spars and ribs) cutouts are provided to reduce the weight, to lay fuel lines and electrical lines and for changing the resonant frequencies of the structures. To provide access to and service of interior parts in aircrafts, openings such as doors and windows are also required. In liquid retaining structures cutouts are needed at the bottom plate for the passage of liquid. Cutouts are required for ventilation purpose also.

This research emphasizes on the effect of cutout shapes and fibre orientation on the buckling analysis of glass/epoxy laminated composite plate. The plate consists of glass as reinforcement and matrix consists of Araldite LY 556 as epoxy resin and Aradur HY 951 as hardener. Bidirectional glass fibres are used here. Most fabric constructions choose bidirectional than straight unidirectional tapes. For aerospace structures, tightly woven fabrics are usually the choice to save weight, minimizing resin void size and maintaining fibre orientation during the fabrication process. Fabrics which are used for structural applications, the fibres or strands used are of same weight or yield in both the warp (longitudinal) and fill (transverse) directions.

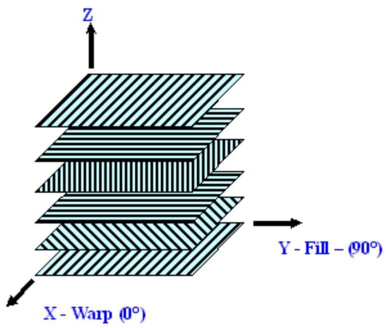

Fig.2. Schematic Representation of Woven Fabric

The present study focuses on the buckling analysis of laminated composite plate by using finite element software using ANSYS.

II. Finite Element Analysis

A Glass/epoxy laminated composite plate of length and width 250 mm was selected for the study. The thickness of each layer was 0.3 mm. The properties of materials were arrived by lab testing of the fibres. The Table 1 shows the material properties of the fibres. Cutouts of area 1964 mm^2 are provided at the centre.

Table 1 Material Properties of Fibre

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

ANSYS 14.5 was used for the buckling analysis of the plate with shell 181 as element. Plates were modelled with different cutout shapes and fibre orientation. Cutout shapes of circular, rectangular and square are provided in the optimized fibre orientated laminated plate. The top and bottom of the plate was fixed as boundary condition. After assigning material properties, the loads were applied as pressure of 1 N/mm^2 for linear buckling analysis.

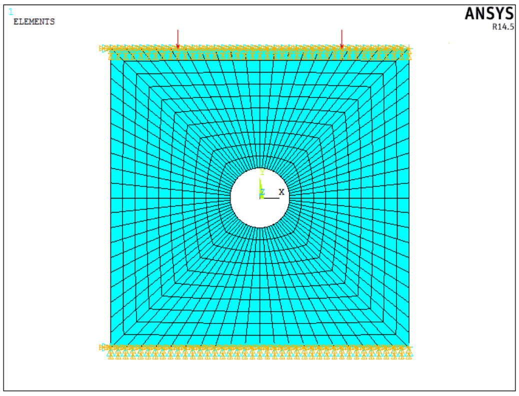

Fig.3. Boundary Condition of Plate with Circular Cutout

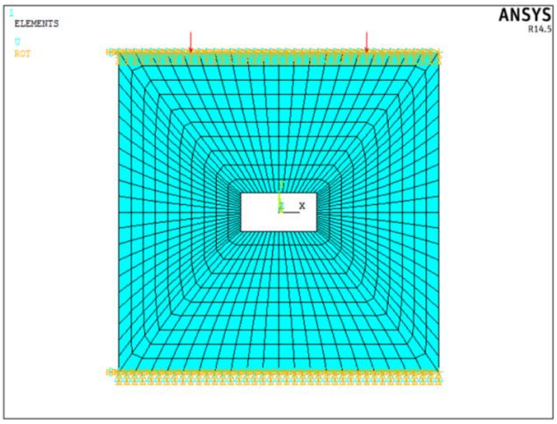

Fig.4. Boundary Condition of Plate with Rectangular Cutout

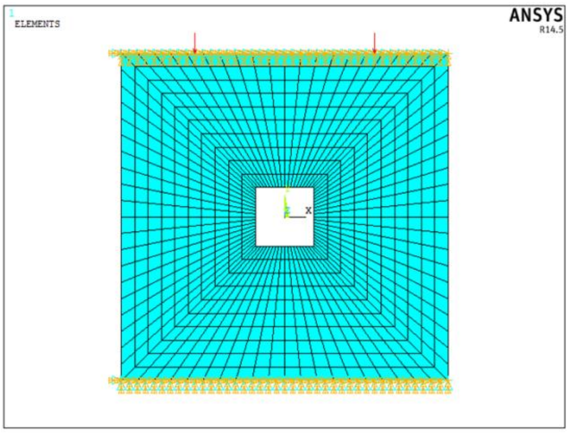

Fig.5. Boundary Condition of Plate with Square Cutout

III. Buckling Analysis Results

3.1 Optimization of Fibre Orientation

Eigen value buckling analysis in the software computes the theoretical buckling load of an ideal elastic structure. It gives the eigen value for the system loading and constraints. To optimize the fibre orientation, the analysis was done with ten combinations of fibre angle with circular cutout. The results obtained are given in the 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

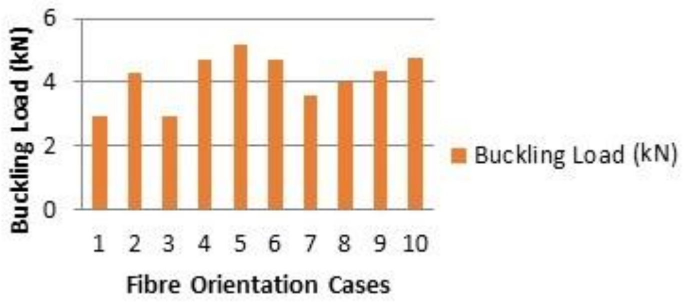

Fig.6. Graph showing the Buckling Load versus Fibre Orientation

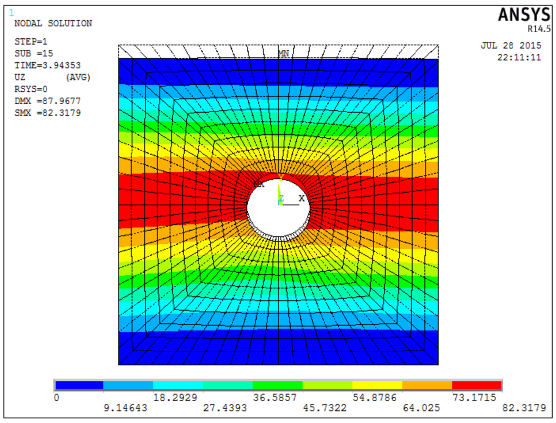

Fig.7. Lateral Deflection of Optimized Laminated Composite Plate

3.2 Optimization for shape of Cutout

To optimize the cutout shape of laminated composite plate, buckling analysis was carried out with rectangular and square cutout with optimized fibre orientation. The buckling load obtained for the optimized fibre orientated laminated composite plate without cutout was 6.9 kN.

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

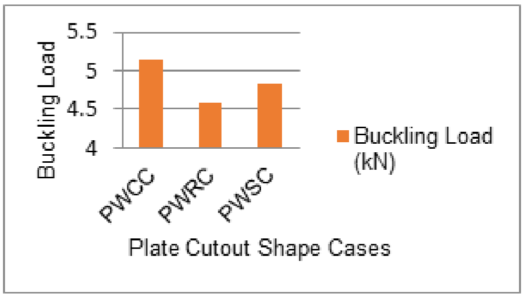

Fig.8. Graph Showing Variation of Buckling Load versus Different Cutouts

IV. Conclusions

Laminated composite materials, in which the layers of different properties are bonded together to act as an integral part. In the present numerical method study with different fibre orientation and different shapes of cutout, the following observations are concluded.

- Buckling load value lowers with increase in fibre angle in the inner layers.
- Maximum buckling load was obtained for laminated composite plate with circular load.
- The maximum buckling load combination was obtained with fibre orientation 0/90/15/-15/15/-15/0/90 with circular cutout.
- Percentage reduction in buckling load due to circular cutout is 25.5 %.

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