BUCKLING ANALYSIS OF THIN CARBON/EPOXY PLATE WITH CIRCULAR CUT-OUTS UNDER BIAXIAL COMPRESSION BY USING FEA

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Abstract

The present research work is to determine buckling load per unit length in rectangular plate with circular cut-outs under bi-axial compression using 2D finite element analysis. The commercial finite element analysis software ANSYS has been successfully executed. The buckling factors are evaluated by changing the position of the holes, length to thickness ratio. The effect of changing the position of holes, a/b ratio, b/t ratio and buckling load per unit length is discussed. The results shows that buckling load per unit length is in clamped-clamped boundary conditions and buckling load is more at top positioned hole, decreases with increase in aspect ratio, decrease with increase breadth to thickness ratio.

Keywords: *Buckling analysis, Finite element method, Buckling load per unit length , carbon/epoxy composite plate, aspect ratio, b/t ratio, and Biaxial load.*

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1. INTRODUCTION

In many engineering structures such as columns, beams, or plates, their failure develops not only from excessive stresses but also from buckling. Buckling behavior significantly changes with change in aspect ratio. Plate seems to work as a Column of finite width at higher aspect ratio. If we decrease aspect ratio, there is also a limit below which failure does not take place by elastic buckling. A.K.Shrivastava & R.K. Singh in 1998 [1] studied the effect of Aspect ratio on buckling behavior. The plates were uni-axially loaded in out of the plane and this problem analyzed by FEM software ANSYS. For reliability analysis mean value first second order, moment method was used. The elastic buckling load of uni-axially loaded rectangular plates of simply supported in the out of the plane direction has been employed by Sawi and Nazmy[4].The buckling analysis of isotropic thin rectangular plates , simply supported along all edges and compressed in one and two orthogonal directions was investigated by Piscopo [5]. He found the buckling load per unit length and buckling stresses for thin and thick rectangular plates by using FEM software, ANSYS and compared these results with classical plate theory. The buckling load of thin FRP laminates subjected to uniaxial compression for varying different boundary conditions, thickness ratios and number of layers was introduced by S. Maheshbabu [6]. The present analysis is extended for the thin rectangular laminates with circular cut outs under biaxial compression.

2. NUMERICAL ANALYSIS

This work is to find buckling load factors of carbon/epoxy rectangular plate subjected to biaxial compression using finite element analysis ANSYS 12. The plate has length a, width b & thickness t. The width of plate is taken as taken as constant b= 1 m. The analysis is done in the following cases:

Case1: The analysis is done by placing center hole in the plate and by its diameter (d) as 0.5m. The Nature of buckling load factor with respect to a/b ratio, b/t ratio is studied.

Case2: Further the work is extended to the analysis by placing bottom hole in the plate. The Nature of buckling load factor with respect to a/b ratio, b/t ratio is studied.

Case3: Next the analysis is done by placing top hole in the plate. The Nature of buckling load factor with respect to a/b ratio, b/t ratio is studied.

3. ELEMENT DESCRIPTION

In this study, 8 node linear layer SHELL99 was selected as the element type. SHELL99 may be used for layered applications of a structural shell model. While SHELL99 does not have some of the nonlinear capabilities of SHELL91, it usually has a smaller element formulation time. SHELL99 allows up to 250 layers. If more than 250 layers are required, a user-input constitutive matrix is available. The element has six degrees of freedom at each node: translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z axes. In the Fig.1 the geometry, node locations, and the coordinate system for this element are shown.

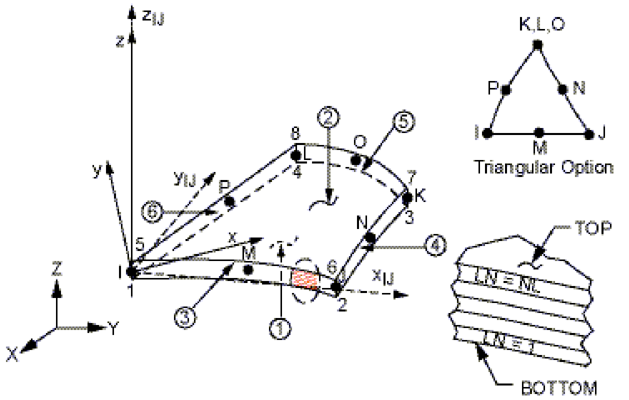


Fig 1: Element geometry of linear layer shell 99

4. GEO-METRIC MODELLING

The length of rectangular plate (a) is varying from 2m, 4m, 6m, 8m, 10m, and 12m y-direction and width of the rectangular plate (b) is 1m, which is fixed in x-direction.

Properties of carbon/epoxy material:

Young's modulus (MPa)	E1= 139x103	E2= 11x103	E3= 11x103
Poission's ratio	V12=0.32	V23=0.46	V13=0.32
Rigidity modulus (MPa)	G12= 4.7x103	G23= 3.7x103	G13= 4.7x103

Then the corresponding "a/b" ratios are 2, 4, 6, 8, 10, 12. The thickness of the plate is determined from the ratio of "b/t" and that is varied as 20, 40, 60, 80 and 100. Then finally the diameter of the circular hole is 0.5m, which is positioned at different locations like top, center and bottom of the plate. The modeling includes defining the element type, real constants, and material property, meshing and it is followed by solution includes buckling analysis. In this study, shell linear layer99 selected as the element type.

5. FINITE ELEMENT ANALYSIS

Finite element analysis includes three steps. (a) Preprocessing (b) Analysis (c) Post processing Preprocessing includes modeling of the plate and applying boundary conditions like constraints, symmetry conditions, and loads.

To model is created with area then the plate is meshed with layered elements after that the load is applied on the plate. The plate is subjected to clamped-clamped boundary conditions. The both ends of the plate are constrained by all degrees of freedom and to the three ends a buckling load of 1 N is applied. Unit loads are usually sufficient (that is, actual load values need not be specified). The eigenvalues calculated by the buckling analysis represent buckling load factors. Therefore, if a unit load is specified, the load factors represent the buckling loads. Here analysis is done in two stages. In the first stage static analysis is done and Pre-stress effects [PSTRES] must be activated. Eigenvalue buckling analysis requires the stress stiffness matrix to be calculated. In the second stage Eigen buckling analysis done. After solving the problem the mode shapes are observed in the post processor. The output from the solution mainly consists of the eigenvalues, which are printed as part of the printed output. The eigenvalues represent the buckling load factors.

6. MESHED MODEL OF CARBON/ EPOXY PLATE AND MODE SHAPES:

Case1: The plate has a central circular hole of diameter d. Here aspect ratio varies from 2 to 12, in the steps of 2. Nature of buckling load per unit length with respect to aspect ratio was studied.

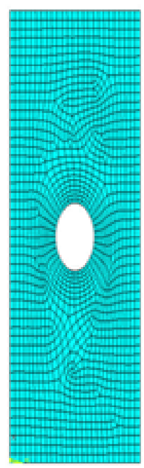


Fig2: Meshed model of carbon/epoxy plate with center hole

Applying loads to plate with center hole:

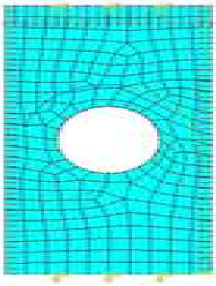


Fig3: Meshed model of carbon/epoxy plate with boundary conditions

The fifth mode shape of plate with center hole is shown in fig.4

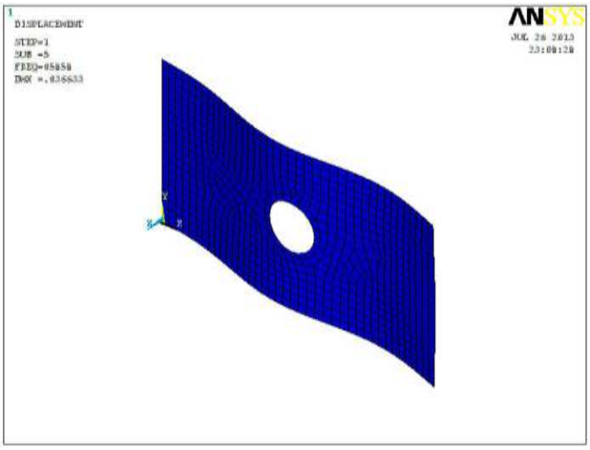


Fig4: mode shape 5 of carbon/epoxy plate with aspect ratio a/b=2

Case2: The plate has a Bottom hole, d. Here aspect ratio varies from 2m to 12m, in the steps of 2m. Nature of buckling load factor with respect to aspect ratio was studied.

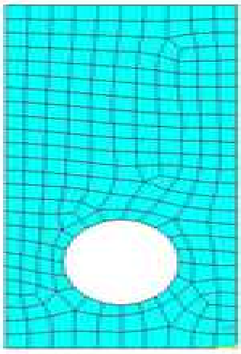
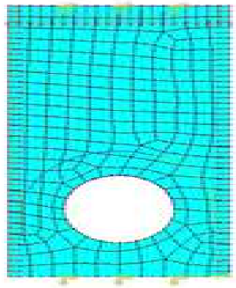


Fig5: Meshed model of carbon/epoxy plate with aspect ratio a/b=2.

Applying loads to plate with bottom hole:



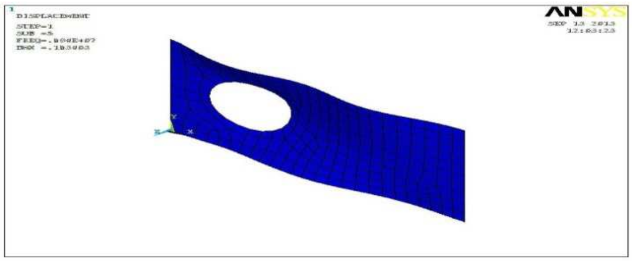


Fig6: mode shape 5 of carbon/epoxy plate with aspect ratio a/b=2

Case3: The plate has a Top hole, d. Here aspect ratio varies from 2m to 12m, in the steps of 2m. Nature of buckling load factor with respect to aspect ratio was studied.

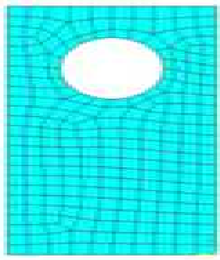
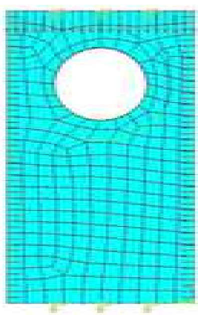


Fig7: Meshed model of carbon/epoxy plate with aspect ratio a/b=2

Applying loads to plate with top hole:



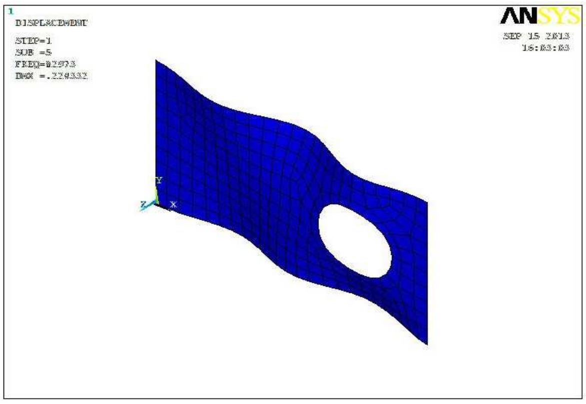


Fig8: mode shape 5 of carbon/epoxy plate with aspect ratio a/b=2

7. RESULTS AND DICUSSIONS

7.1 Comparison of Buckling Load for Top, Center &Bottom Hole:

From the fig.9 it is observed that the buckling load is high for plate with top hole. The buckling load values for plate with bottom hole are very near to the values of top hole. The buckling load values for plate with center hole are less when compared with others.

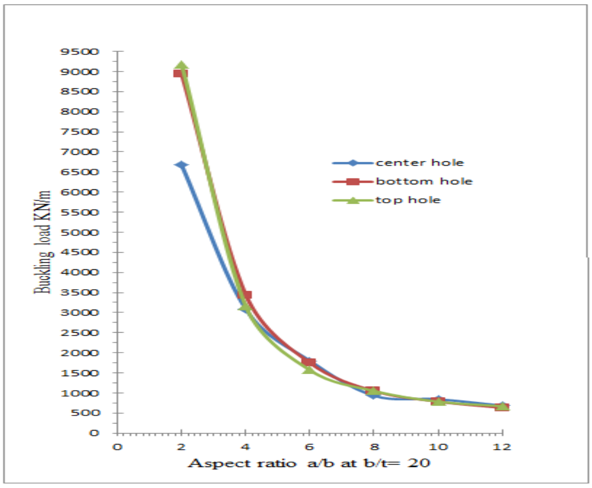


Fig. 9: Comparison of buckling load with aspect ratio at various position of hole

Case1: The fig.10 shows variation of aspect ratio a/b for plate with center hole. It is observed that as a/b ratio increases the buckling load decreases.

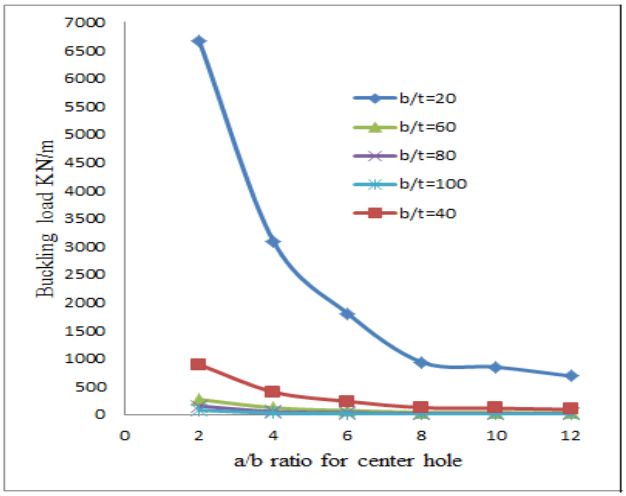


Fig. 10: Comparison of buckling load with aspect ratio for plate with center hole at various b/t ratios

The fig.11 is showing the variation of mode5 buckling load values at various b/t ratios at aspect ratio a/b=2. It is observed that as the b/t ratio increases the buckling factor decreases. As the b/t ratio increase from 20 to 40 the buckling factor nearly decreased by 7.5 times. As the b/t ratio increase from 40 to 60 the buckling factor nearly decreased by 3.3 times. As the b/t ratio increase from 60 to 80 the buckling factor nearly decreased by 2.33 times. As the b/t ratio increase from 80 to 100 the buckling factor nearly decreased by 1.97 times .So the buckling factor decreases with the increase in b/t ratio and at the initial stages it is high such as 7.5 and at the final stages it reduced to 1.97.

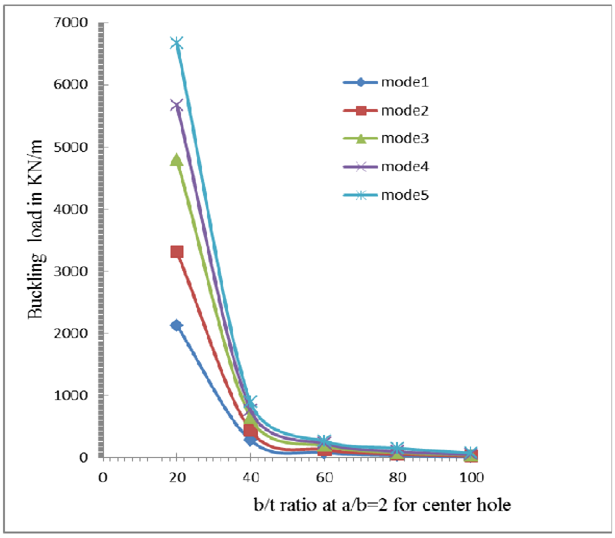


Fig. 11: Comparison of buckling load with b/t ratio for center hole at a/b=2

Case2: The fig.12 shows variation of aspect ratio a/b for plate with bottom hole. It is observed that as a/b ratio increases the buckling load decreases. The fig.12 is showing the variation of mode5 buckling load values at various b/t ratios at. Aspect ratio a/b=2. It is observed that as the b/t ratio increases the buckling factor decreases. As the b/t ratio increased from 20 to 40 the buckling factor nearly decreased by 7.8 times .As the b/t ratio increased from 40 to 60 the buckling factor nearly decreased by 3.3 times. As the b/t ratio increase from 60 to 80 the buckling factor nearly decreased by 2.33 times. As the b/t ratio increased from 80 to 100 the buckling factor nearly decreased by 1.95 times .So the buckling factor decreases with the increase in b/t ratio and at the initial stages it is high such as 7.8 and at the final stages it reduced to 1.95.

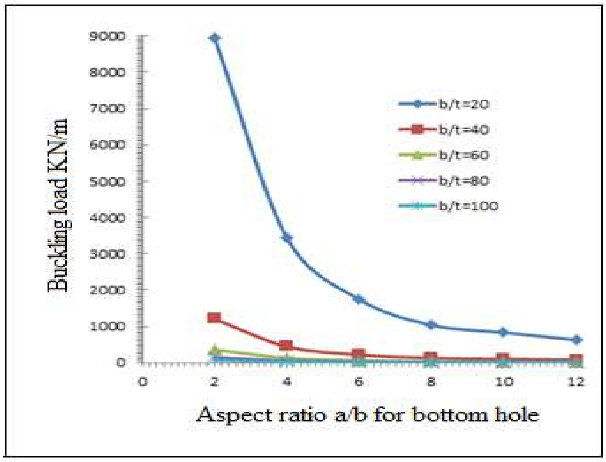


Fig.12: Comparison of buckling load with aspect ratio for plate with bottom hole at various b/t ratios.

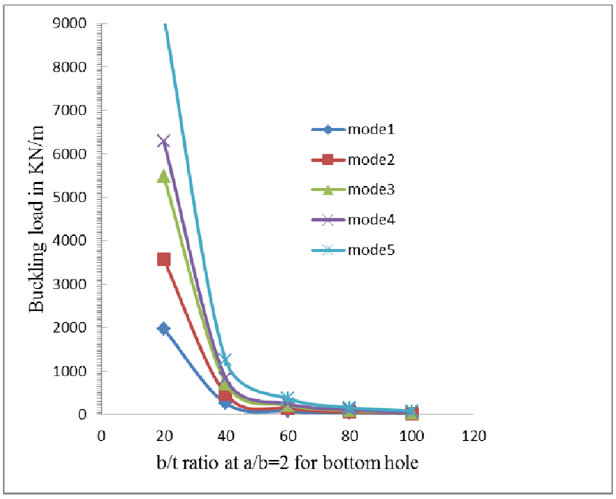


Fig.13: Comparison of buckling load with b/t ratio for plate with bottom hole at a/b=2.

Case3: The fig.14 shows variation of aspect ratio a/b for plate with bottom hole. It is observed that as a/b ratio increases the buckling load decreases. The fig.14 is showing the variation of mode5 buckling load values at various b/t ratios at. Aspect ratio a/b=2. It is observed that as the b/t ratio increases the buckling factor decreases. As the b/t ratio increased from 20 to 40 the buckling factor nearly decreased by 7.8 times .As the b/t ratio increased from 40 to 60 the buckling factor nearly decreased by 3.3 times. As the b/t ratio increase from 60 to 80 the buckling factor nearly decreased by 2.33 times. As the b/t ratio increased from 80 to 100 the buckling factor nearly decreased by 1.95 times .So the buckling factor decreases with the increase in b/t ratio and at the initial stages it is high such as 7.8 and at the final stages it reduced to 1.95.

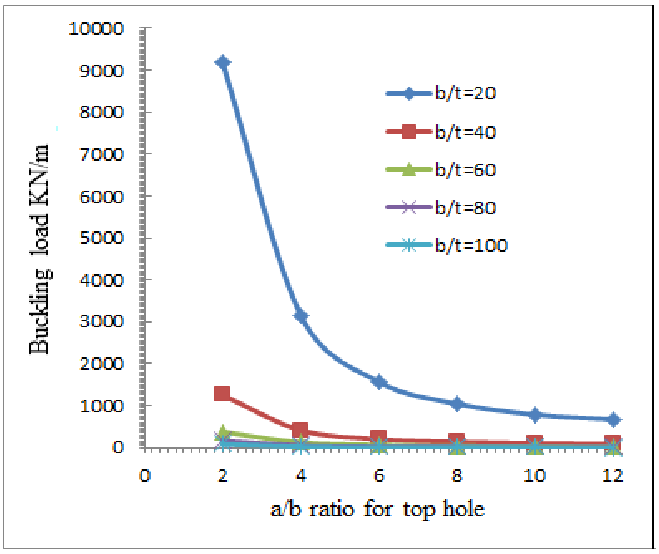


Fig14: Comparison of buckling load with aspect ratio for plate with top hole at various b/t ratios.

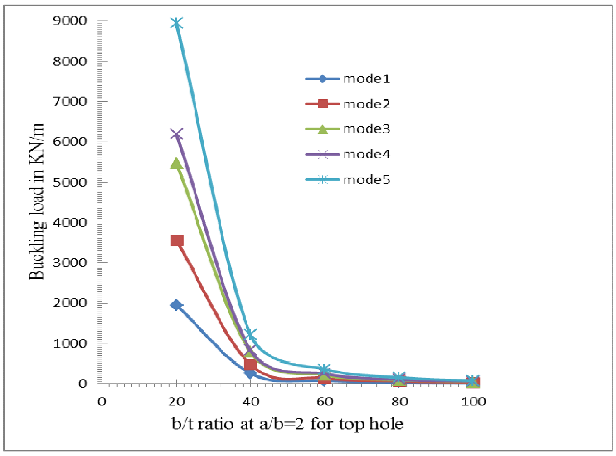


Fig15: Comparison of buckling load with b/t ratio for plate with top hole at a/b=2

CONCLUSIONS

This study considers the buckling response of laminated carbon/ epoxy with clamped-clamped boundary conditions. The laminated composite plates have varying aspect ratio, varying breadth to thickness b/t ratio, cut out shape and changing places of holes are considered. From the present analysis, the following conclusions are made:

- It was noted that the buckling load/unit length decreases with increases of aspect ratio
- As the b/t ratio increases the buckling load decreases.
- The plate with top hole had more buckling load/ unit length compared with bottom and center hole.
- The study is useful in selecting the above said parameters in designing the laminates in buckling point of view

FUTURE SCOPE OF WORK

1. Providing multiple notches & removal of material around the discontinuity is to be done.
2. Study Post buckling behavior of laminated composite material, for which a nonlinear analysis is to be performed.

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