Buckling Analysis of Thin Carbon/Epoxy Plate by Using FEA

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ABSTRACT

In this paper a carbon/epoxy composite thin plate having four lamina with fiber orientation ($0^0/90^0/90^0/0^0$) is selected for analysis. The plate has length a, width b& thickness t. The Nature of buckling load factors with respect to Aspect ratio is studied. In the next step nature of buckling load factors with respect to t/b ratio is studied. The commercial finite element analysis software ANSYS has been successfully executed and the finite element model is validated. Buckling load factors have been determined for different aspect ratio by introducing cutouts and multiple holes (d/b ratio & d/d_1 ratio). The buckling load factor decreases as the aspect ratio increases. As the d/b ratio increases, buckling load factor decreases. It was seen that buckling load factor decreases with increase of d_1/d ratio. Since localization of stress concentration is reduced by providing the multiple holes around the cut out shape. The reduction of the buckling load due to the presence of a cutout is found to be significant. It is noted that the presence of cutout lowers the buckling load factor.

Key words: Buckling load factor, carbon/epoxy composite plate, aspect ratio, t/b ratio, d/b ratio, d/d_1 ratio.

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, d/b ratio, d_1/d 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.In this paper an attempt has been made to study the effectof aspect ratio, d/b & d_1/d on the buckling of laminated Composite plates by FEA using ANSYS.

2. NUMERICAL ANALYSIS

This work is to find buckling load factors of carbon/epoxy rectangular plate subjected to uniaxial compression using finite element analysis ANSYS 11. The plate has length a, width b & thickness t. The width of plate is taken as taken as constant b= 1m. The analysis is done in the following cases:

Case1:

The Nature of buckling load factor with respect to Aspect ratio is studied. Here Aspect ratio varies from 2 to 12.
In the next step nature of buckling load factor with respect to t/b ratio is studied. Here the buckling factors at various t/b ratio's such as 1/20, 1/40, 1/60, 1/80 and 1/100 is calculated using ANSYS. The effect of buckling factor, stress concentrations in the plate is studied.

Case2:

Next the analysis is done by placing center hole in the plate and by varying its diameter (d). The Nature of buckling load factor with respect to d/b ratio is studied. The effect on stressconcentration zones in the plate are studied due to center hole.

Case3:

Further the work is extended to the analysis by placing multiple holes in the plate and by varying their diameters (d_1). The Nature of buckling load factor with respect to d_1/d ratio is studied. The effect on stress concentration zones in the plate is studied due to multiple holes.

3. ELEMENT DESCRIPTION

In this study, 8 node linear layer shell 99 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 2 the geometry, node locations, and the coordinate system for this element are shown.

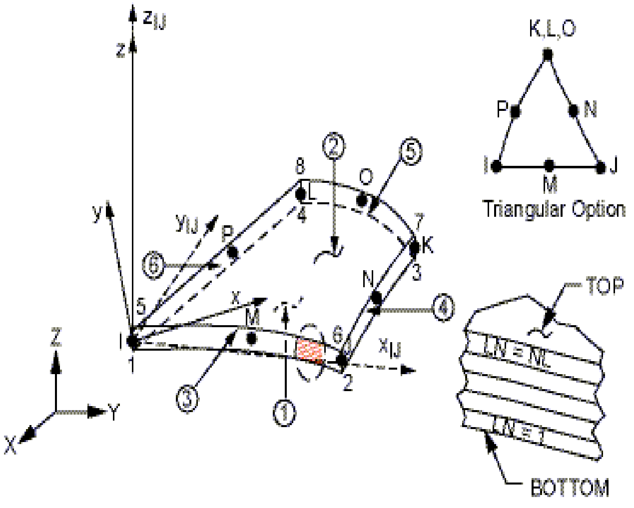


Fig 1: Element geometry of linear layer shell 99

4. FINITE ELEMENT ANALYSIS

Finite element analysis includes three steps. (a) Preprocessing (b) analysis (c) post processing. Preprocessing includes modeling of the plateand applying boundary conditions like constraints, symmetry conditions, and loads. The carbon/epoxy plate is considered as anorthotropic material with following properties:

Young's modulus (MPa)	E_1= $139x10^3$	E_2= $11x10^3$	E_3= $11x10^3$
Poission's ratio	V_{12}=0.32	V_{23}=0.46	V_{13}=0.32
Rigidity modulus (MPa)	G_{12}= $4.7x10^3$	G_{23}= $3.7x10^3$	G_{13}= $4.7x10^3$

To create model first area is created. Then the plate is meshed. Then load is applied on the plate. The plate is subjected to clamped-free boundary conditions. The left end of the plate is constrained by all degrees of freedom and to the right end 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. Hereanalysis is done in two stages. In the first stage static analysis is done and Prestress 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 and normal stress distribution is 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.

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

Case1:

A composite plate having four lamina with dimensions (a*b*t). Nature of buckling load factor with respect to aspect ratio is studied. Here Aspect ratio varies from 2to 12. Where a, b, t are the length, width & thickness of the plate respectively.

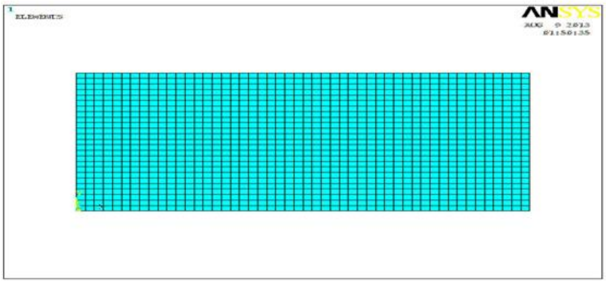
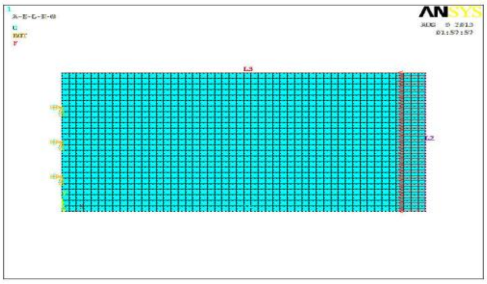


Fig2: Meshed model of carbon/epoxy plate with aspect ratio a/b=2.

Applying loads to plate:



The fifth mode shape the plate is shown below

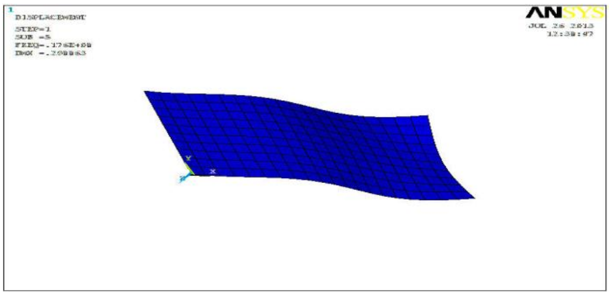


Fig3: mode shape 5 of plate of a/b=2, t/b=1/20

Case2:

The plate has a central circular cut out of varying diameter, d. Here d/b ratio varies from 0.05 to 0.3, in the steps of 0.05. Nature of buckling load factor with respect to d/b ratio was studied.

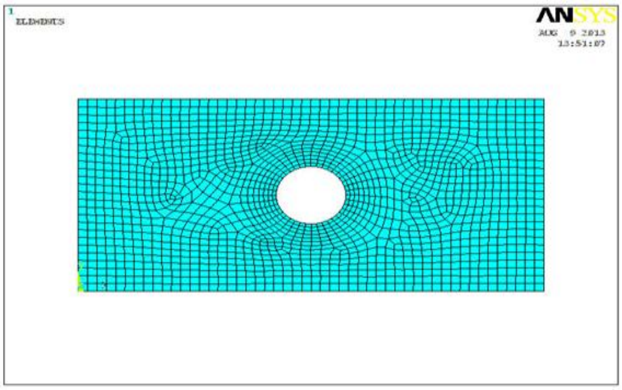


Fig4: Meshed model of carbon/epoxy plate with aspect ratio a/b=2, d/b= 0.3.

The fifth mode shape of plate with center hole is shown below:

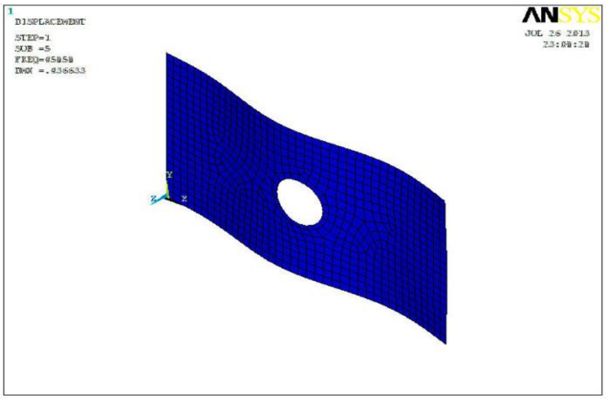


Fig5: mode shape 5 of carbon/epoxy plate with aspect ratio a/b=2, d/b=0.3.

Case3:

The plate has a Centre hole, d along with multiple holes of varying diameter d1. Here d_1/d ratio varies from 0.05 to 0.3, in the steps of 0.05.

Nature of buckling load factor with respect to d_1/d ratio was studied.

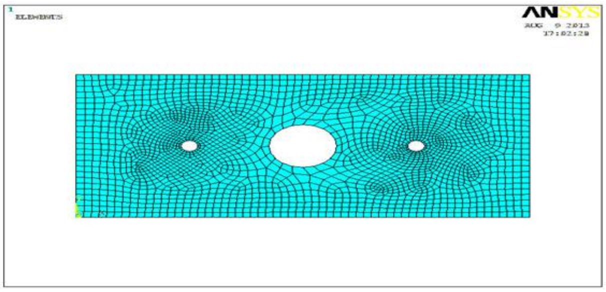


Fig6: Meshed model of carbon/epoxy plate with aspect ratio a/b=2, d_1/d= 0.3.

The fifth mode shape of plate with multiple holes is shown in fig7.

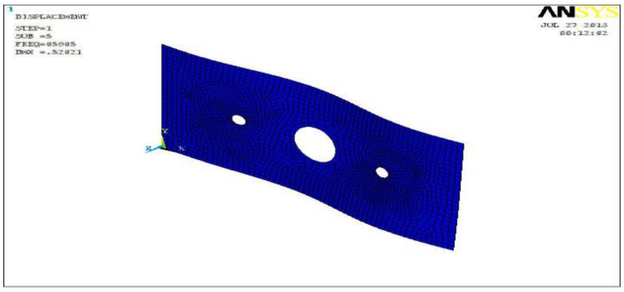


Fig7: mode shape 5 of carbon/epoxy plate with aspect ratio a/b=2, d_1/d=0.3.

6. RESULTS AND DICUSSIONS

Case1:

The fig8 is showing the variation of mode 5 buckling factor at various t/b ratios vs. aspect ratio. It is observed that as the t/b ratio decreases the buckling factor decreases.As the t/ b ratio decreased from 1/20 to 1/40 the buckling factor nearly decreased by 7.8 times .As the t/ b ratio decreased from 1/40 to 1/60 the buckling factor nearly decreased by 3.4 times. As the t/ b ratio decreased from 1/60 to 1/80 the buckling factor nearly decreased by 2.34 times .As the t/ b ratio decreased from 1/80 to 1/100 the buckling factor nearly decreased by 1.95 times .So the buckling factor decreases with the decrease in t/b ratio and at the initial stages it is high such as 7.8 and at the final stages it reduced to 1.95.

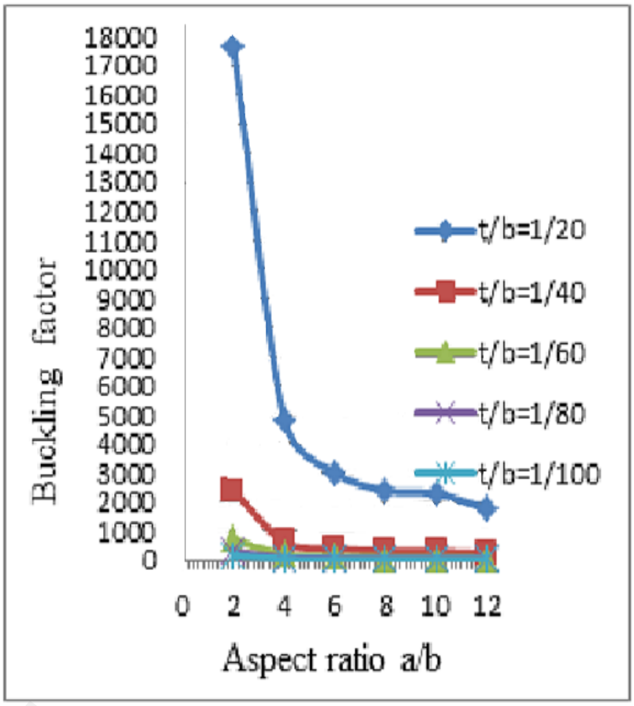


Fig8: Variation of mode 5 buckling factor vs. aspect ratio at various t/b ratios

The variation of normal stresses in x direction and their distribution in the plate at various aspect ratios is shown in the figures below. It is observed that as the aspect ratio increases the stress effected zone decreases this is to be compared with stress contraction in the plate due to cut out and because of multiple holes.

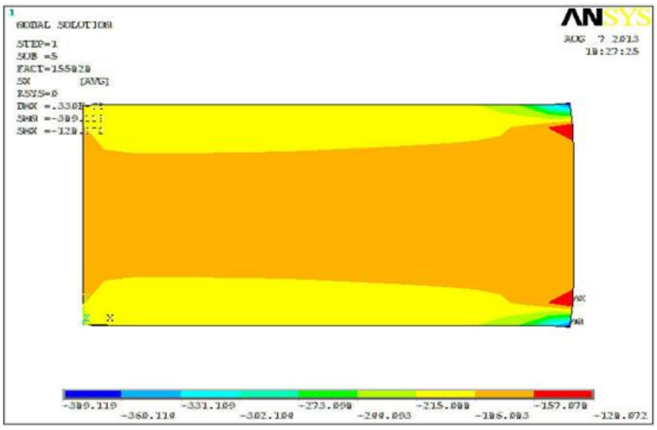


Fig 9: contour plot with aspect ratio at a/b=2

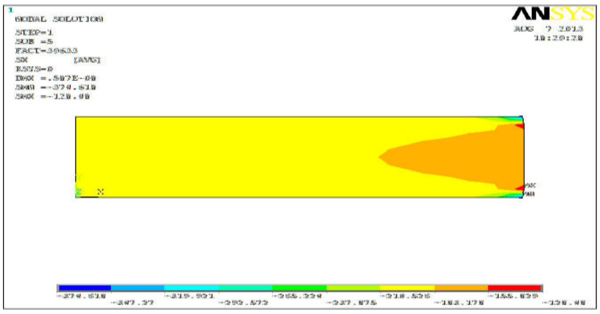


Fig 10: contour plot with aspect ratio at a/b=4

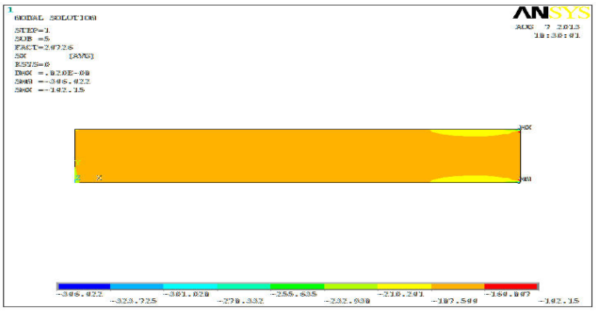


Fig 11: contour plot with aspect ratio at a/b=6

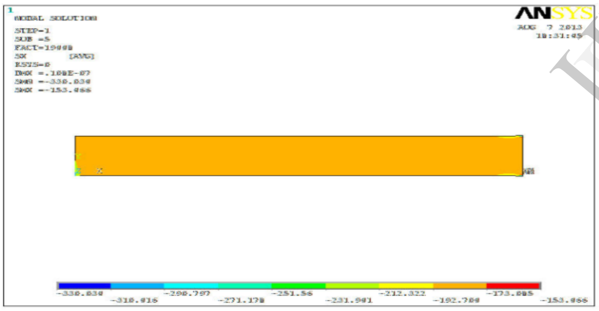


Fig 12: contour plot with aspect ratio at a/b=8

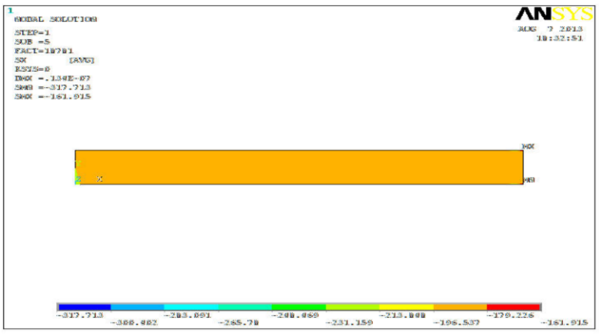


Fig 13: contour plot with aspect ratio at a/b=10

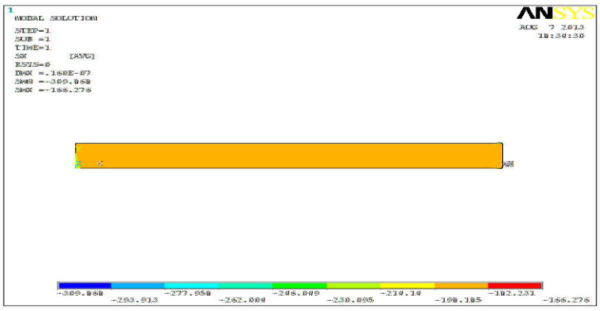


Fig 14: contour plot with aspect ratio at a/b=12

Case2:

Hear d/b ratio various from 0.05 to 0.3. Nature of buckling load factor with respect to d/b ratio is studied. The of stress constration due to center cut out is also studied.From the figure15 it observed that the buckling factor decreases with increases of aspect ratios for the plate with center hole. Because of the hole in the plate the buckling factor decreased when compared with bear plate.

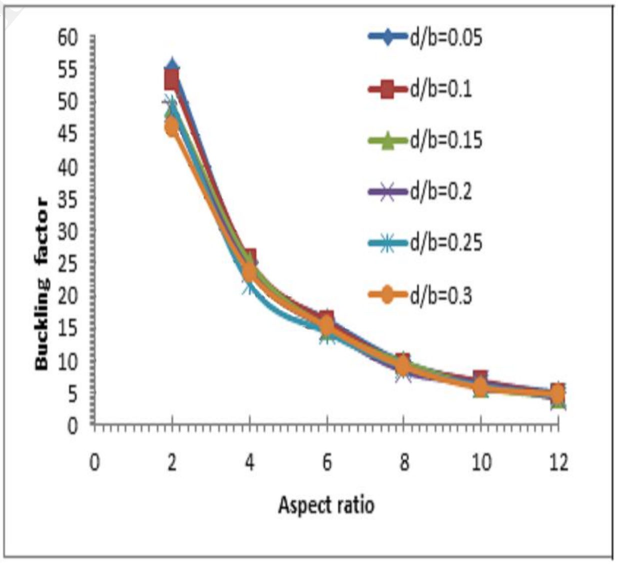


Fig 15: Buckling factor vs. a/b at various d/b ratio

From the figure 16 it is observed that with increase of d/b ratio from 0.05 the buckling factor decreases up to 0.15 further slightly increased up to 0.2 then decreased up to 0.3.

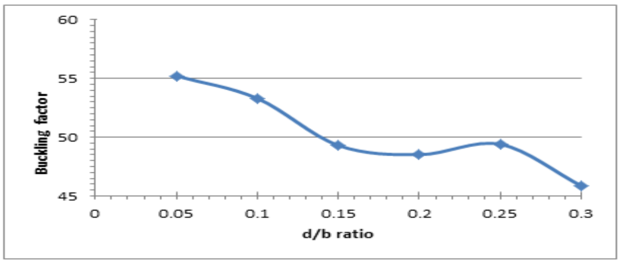


Fig 16: Mode5 buckling factors vs. d/b ratio

The below Figures shows the normal stress distribution in x direction because of application of buckling load to the plate with center hole. It is observed that the stress concentration zone increases in the plate because of the center hole. It is to be decreased by incorporating small multiple holes in the plate.

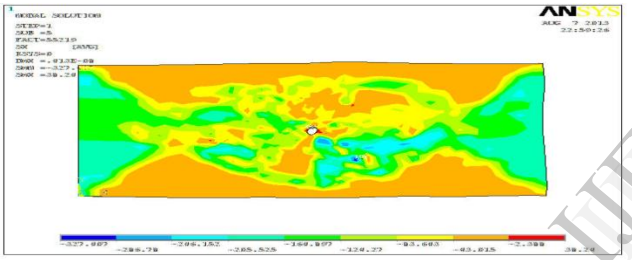


Fig 17: contour plot with a/b=2,d/b=0.05

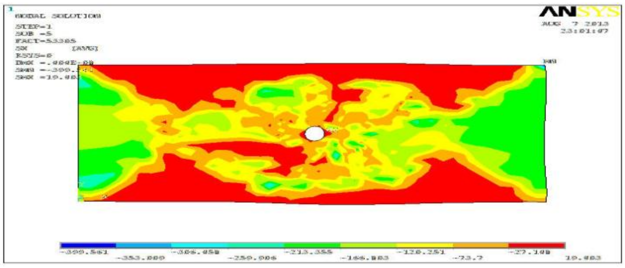


Fig 18: contour plot with a/b=2,d/b=0.1

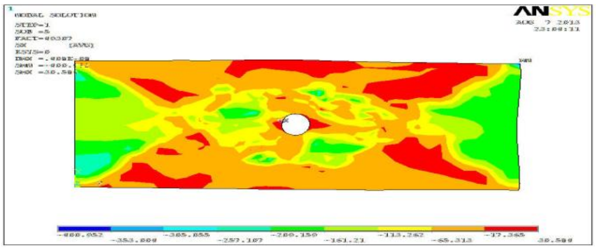


Fig 19: contour plot with a/b=2,d/b=0.15

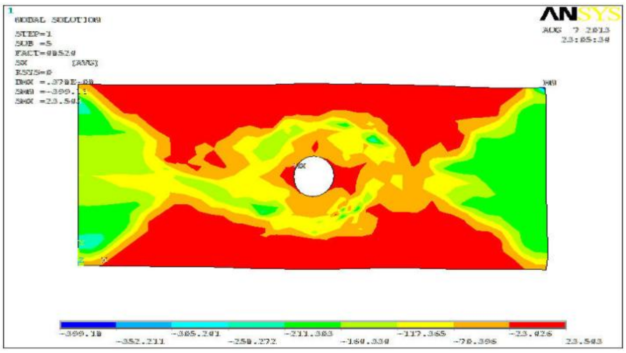


Fig 20: contour plot with a/b=2,d/b=0.2

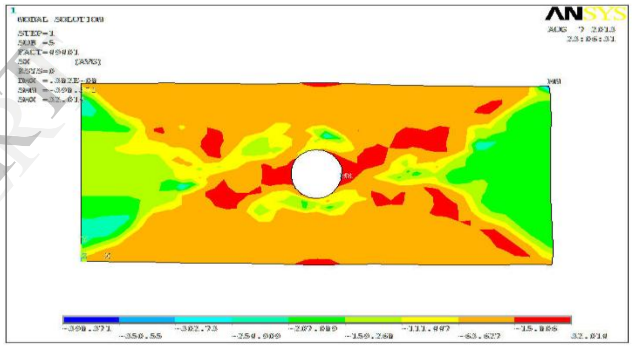


Fig 21: contour plot with a/b=2,d/b=0.25

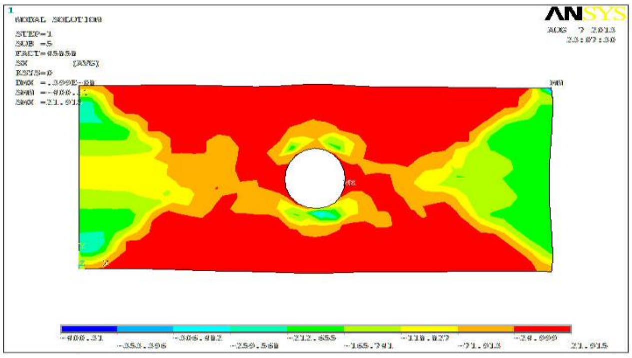


Fig 22: contour plot with a/b=2,d/b=0.3

Case3:

To study the effect of stress concentration due to cut out small multiple hole are provided near the center hole. Let $d_1$be the diameter of small multiple holes. The effect of buckling factor by varying d_1 /d from 0.05 to 0.3 is studied by taking a/b=2, t/b=1/100. From the fig23 the buckling factor decreases with the increase of aspect ratio for plate with multiple holes at variousd$_1$/d ratios.

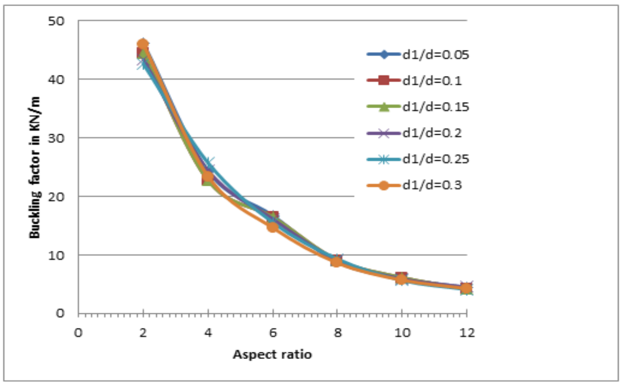


Fig 23: Mode 5 buckling factor vs a/b at various d_1/d ratios

From the fig24 with the increase of d_1/d ratio buckling factor decreases up to d_1/d =0.25 and then increases.

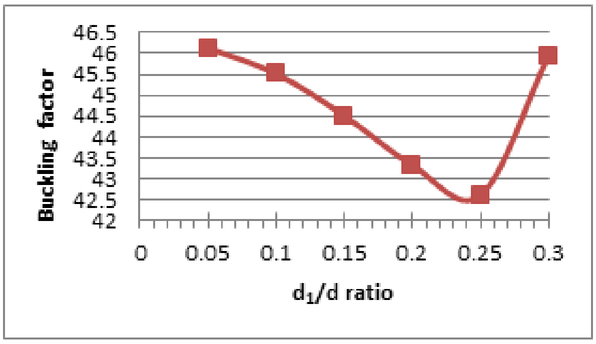


Fig 24: Buckling factor vs. d_1/d ratio

From the belowfigures it is observed that stress concentration zone because of center hole is decreased considerably by incorporating multiple holes.

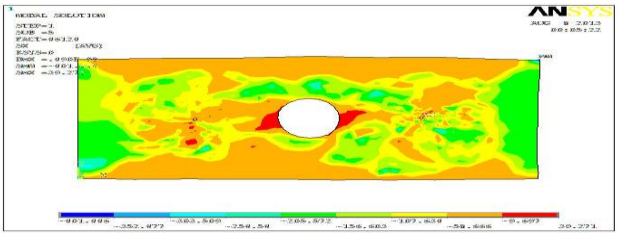


Fig 25: Contour plot at a/b=2,d_1/d=0.05

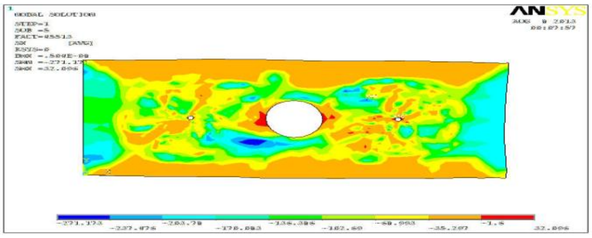


Fig 26: Contour plot at a/b=2,d_1/d=0.1

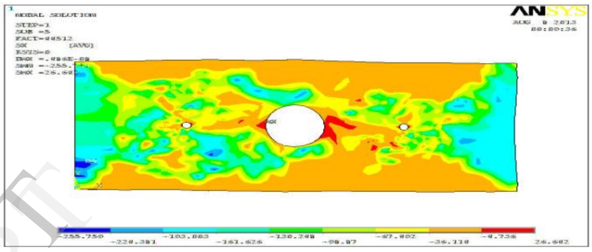


Fig 27: Contour plot at a/b=2,d_1/d=0.15

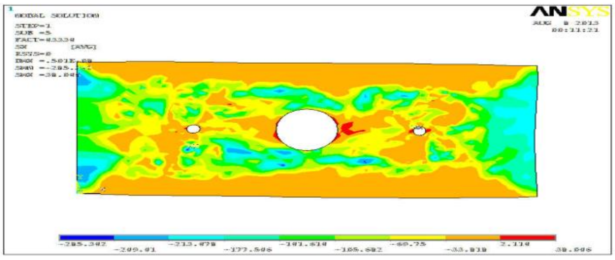


Fig 28: Contour plot at a/b=2,d_1/d=0.2

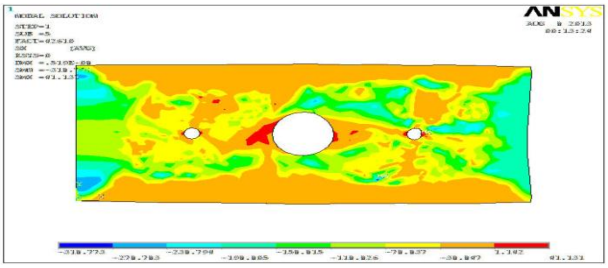


Fig 29: Contour plot at a/b=2,d_1/d=0.25

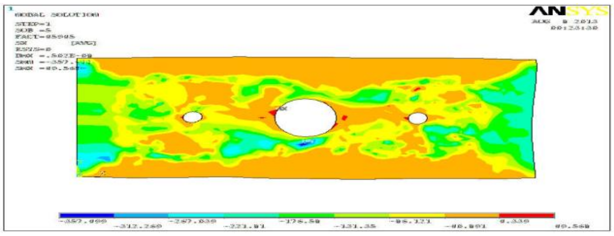


Fig 30: Contour plot at a/b=2,d_1/d=0.3

7. CONCLUSIONS

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

- It was noted that the buckling factor decreases with increases of aspect ratio
- As the t/b ratio decreases the buckling factor decreases.
- The presence of center hole causes decrease in buckling factor and increase of stress concentration zones.

The incorporation of multiple holes causes the decrease in buckling factor and decrease in stress concentration zones.

8. 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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