International Journal of Scientific Engineering and Technology (ISSN : 2277-1581)
www.ijset.com, Volume No.1, Issue No.4, pg : 93-95 01 Oct. 2012

Buckling Behavior of an Orthotropic Composite Laminate using Finite Element Analysis

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Abstract: The effect of fibre orientation on buckling behaviour in a rectangular composite laminate with central circular hole under uniform in-plane loading has been studied by using finite element method. The critical buckling loads with different fibre orientation in an orthotropic composite laminate (E-glass/epoxy) were obtained. The deformation behaviour of the plate is shown for modes, i=1,2. Studies are carried out for three D/A ratio (where D is hole diameter and A is plate width) with different plate thickness (number of layers). The finite element formulation is carried out in the analysis section of the ANSYS software.

Keywords: orthotropic composite laminates, fibre orientation, buckling analysis, eigen value, ANSYS

I. INTRODUCTION

Composite laminated plates when loaded in compression are subjected to a type of behavior known as buckling as long as the load on the plate is relatively small, then any increase in the load results only in an axial shortening of the plate. However once a certain critical load is reach, the plate suddenly bows out sideways. This bending gives rise to large deformations, which cause the plate collapse. The load at which buckling occurs is thus a design criterion for compression plate. Plates with circular and other holes are extensively used as structural members in aircraft design. The buckling behavior of such plate has always received much concentration by investigators. Ghannadpour et al[1] found out that plates that have a cutout can buckle at higher buckling load compare to plates without cutout. Kremer et al[2] studied the influence of the shape of optimized cutouts on the buckling behaviour. Tercan et al[3] studied the cutout shape effect on buckling behaviour. Eryigit et al[4] investigate the effect of hole diameter and its location on the lateral buckling behavior(woven fabric). Komur et al[5] studied the buckling analysis with circular/elliptical hole, numerically(woven glass polyester). Kumar et al[6] observed that the cutout shape has considerable effect on the buckling and post buckling behaviour(quasi-isotropic laminate) with large size cutout. Ameen et al[7] determine the critical buckling load of E-glass reinforced polyester plastic material experimentally.

The main purpose of the present work is to study the effect of fibre orientation (0^0,30^0,45^0, 60^0) on buckling behaviour in composite plate. The analysis involved obtaining the eigenvalue buckling loads in which the following parameters were examined: a) the D/A ratio (where D is hole diameter and A is plate width). b) fibre orientation. c) Plate thickness (number of layers). As the analytical treatment for such problem is very difficult, the investigation is carried out using ANSYS software.

II. DESCRIPTION OF PROBLEM

For analysis, a composite plate of dimension 0.3m x 0.45m x 0.003m with a central hole of diameter D subjected to uniform in-plane loading for all cases analyzed by finite element method. The numerical analysis is carried out for three different D/A ratios as 0.1, 0.2, 0.5 with different plate thickness (number of layer as 3, 5). Figure 1 show the basic model of the problem.

III. FINITE ELEMENT ANALYSIS

An eight nodded layered structural 3D shell element (shell91) with six degree of freedom at each node was selected based on convergence test and used throughout

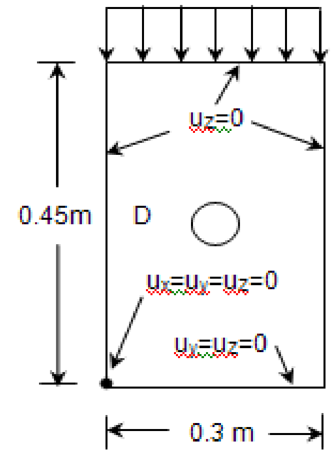

Figure 1. Basic Model (A plate with central hole)

the study. Each node has six degree of freedom, making total of 48 degrees of freedom per node. Due to unsymmetric nature of different system investigation, the full composite plate is discretize for each system for finite element analysis. Critical buckling loads (Nx,cr) were obtained from composite plate for two mode shape (i=1 and i=2). Buckling of laminated composite rectangular plate was analysed for different fibre orientations, different D/A ratio and different number of layers. Figure 2 show the element detail.

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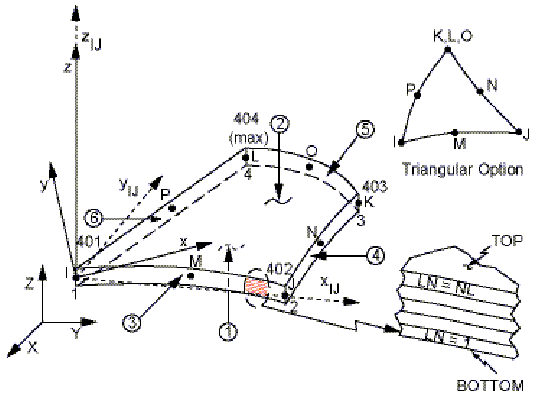

Figure2. Detail of element type

IV. Result and Discussion

Numerical Results are presented for E-glass/epoxy. The Material properties of the composite plate are shown in Table 1. Where; E,G and μ represent modulus of Elasticity, modulus of rigidity and poisson's ratio respectively.

Material	E-Glass Epoxy
E_x	39GPa
E_y	8.6GPa
G_{xy}	3.8GPa
ν_{xy}	0.28

Table 1: Material Properties of Composite Plate

Table 2 and Table 3 show the critical buckling load under mode (i=1,2) for different fibre orientation and D/A ratio (for 3 and 5 number of layers). From Table 2 and Table 3, it is being observed that in some cases, the buckling load have shown the different type of trend compare to normal expectation, i.e. in circular cutouts buckling load first decreased and then increased and afterwards finally goes decreasing with increase of D/A ratio.

Based on this observation about the difference and decrease in buckling load in presence of cutout, the possible cause may be outlined due to two effects. i) stress concentration and ii) Material removal effect, and accordingly various zones of decreasing buckling load may be classified as

a) Stress dominant zone
b) Stress concentration and material removal dominant zone
c) material removal dominant zone
d) web dominant zone

Mode	Fibre Orientation	Nx,cr (kN)			
		without hole	D/A ratio		
			0.1	0.2	0.5
i=1	0^0	3.95	3.82	3.61	3.48
	30^0	4.65	4.43	4.31	4.20
	45^0	5.13	4.95	4.74	4.60
	60^0	5.87	5.50	5.32	5.06
i=2	0^0	4.855	4.355	3.75	3.46
	30^0	5.465	5.102	4.74	4.53
	45^0	5.696	5.467	5.27	5.16
	60^0	5.936	5.764	5.53	5.35

Table 2: Critical buckling load under mode (i=1,2) in different fibre orientations and D/A ratio for composite plate with 3 layers.

Mode	Fibre Orientation	Nx,cr (kN)			
		without hole	D/A ratio		
			0.1	0.2	0.5
i=1	0^0	17.91	17.21	16.85	16.32
	30^0	19.98	18.86	18.26	18.14
	45^0	22.16	21.08	20.82	20.35
	60^0	23.74	23.24	23.16	22.26
	0^0	21.69	19.35	18.93	17.68
	30^0	23.91	22.36	20.68	19.74
	45^0	25.72	24.71	23.09	22.24
	60^0	27.69	26.86	24.93	24.11

Table 3: Critical buckling load under mode (i=1,2) in different fibre orientations and D/A ratio for composite plate with 5 layers.

V. Conclusions

The buckling behaviour of an orthotropic laminated composite plate with circular hole subjected to inplane loading has been studied by finite element method. Effect different fibre orientation, different D/A ratio, number of layers on the critical buckling load of rectangular plate have been investigated. Based on the findings, the following conclusions can be made.

- Presence of cutout reduces the buckling load due to stress concentration and material removal effect.
- The critical buckling load varies with increased of D/A ratio.
- The critical buckling load increases with increase in the angle of orientation (from 0^0 to 60^0).
- The buckling load is directly proportional with plate thickness (no. of layers).
- Material removal effect goes increasing with increase in D/A ratio.
- Stress concentration effect is more important than the material removal effect provided that the dimension of cutout is not so large with respect to the plate dimension that side web become dominant.

References

[1] Ghannadpour, Najafid, Moammadi," On the buckling behaviour of cross-ply laminated composite plates due to circular/elliptical cutouts", Jr Composite Structures, Vol.75, 2006.

[2] Kremer, Schurmann,"Buckling of tension loaded thin-walled composite plates with cutouts", Jr composite Science and Technology, Vol. 68,2008.

[3] Tercan,Aktas,"Buckling behaviour of 1_1 rib kitting laminated plate with cutouts", Jr Composite Structures, Vol.89, 2009.

[4] Eryigit, Zor, Arman,"Hole effect on lateral buckling of laminated cantilever beams", Jr Composite: Part B, Vol.40, 2009.

[5] Komor, Sonmez," Elastic buckling of rectangular plateunder linear varying in-plane normal load with circular

cutouts", Jr. Mechanics Research Communications,Vol.35, 2008.

[6] Kumar, Singh," Effect on boundary conditions on buckling and post buckling responses of composite laminates with various shaped cutouts", Jr Composite Structures, Vol.92, 2010.

[7] Ameen,"Buckling Analysis of composite Laminated plate with cutouts", Engg. And Tech. Jr., Vol.27, No.8, 2009.

[8]ANSYS User's Manuel (Version 9.0)

[9]R.M.Jones, Mechanics of Composite Materials, McGraw Hill, Tokyo, 1975.

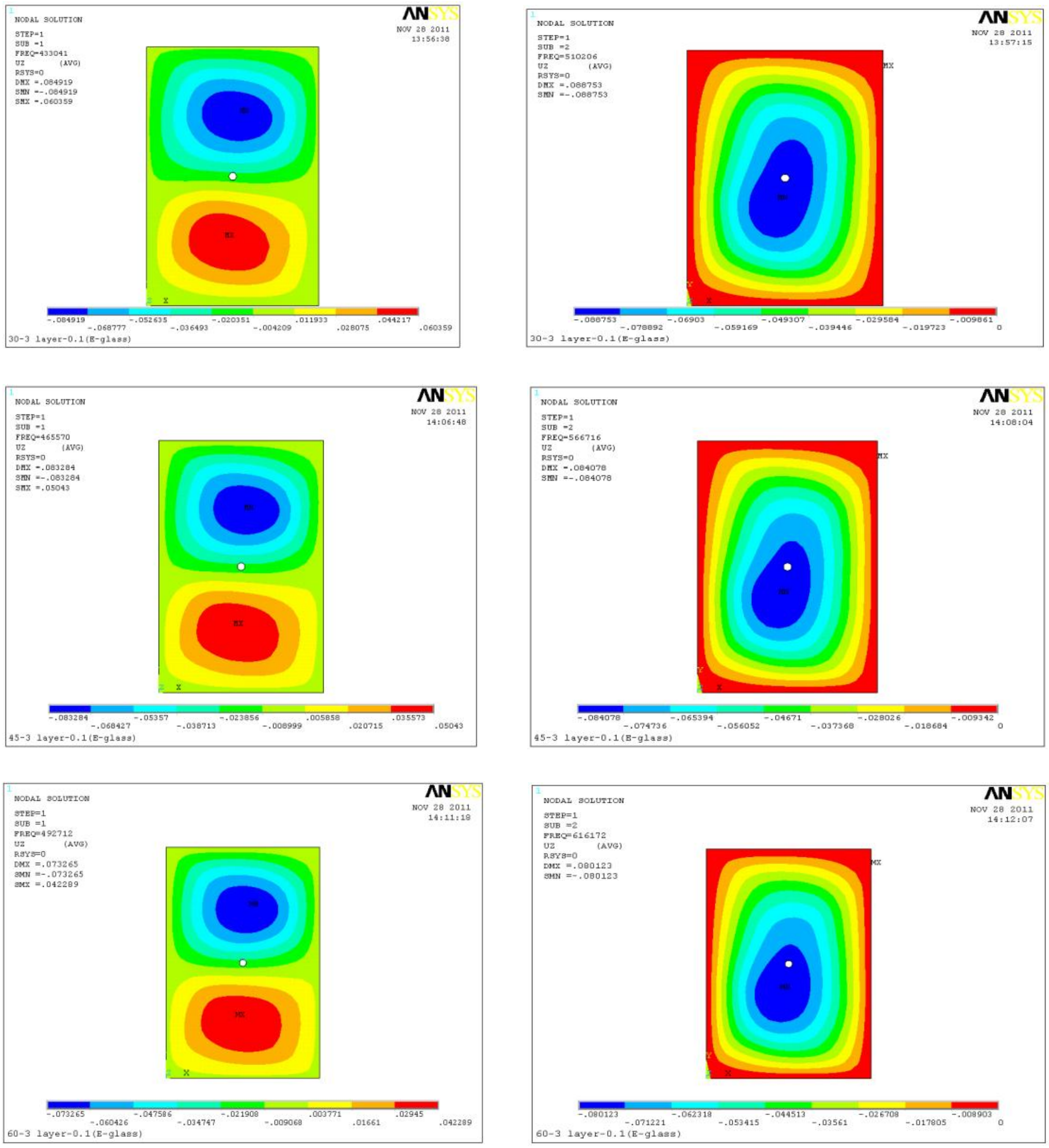

Figure 3. Counter plot of uz field(z-displacement) under buckling modes (i=1,2) with D/A ratio(0.1) for fibre orientation 30^0,45^0,60^0 of composite plate with 3 number of layers.