ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Model Analysis of Centre Circular Cutout of Laminated Composite Plate and Square Skew Plate by using FEM

Deepanshu Bhatt*, Yogesh Mishra, Dr. P.K. Sharma
* M.Tech Scholar Student, Mech. Depart., NIIST Bhopal, India
Associate Prof. Mechanical Department, NIIST Bhopal, India
HOD & Co-Guide of Mechanical Department, NIIST Bhopal, India

Abstracts

A "composite" is when two or more different materials are combined together to create a superior and unique material. This research presents an experimental of the Model analysis of Centre circular laminated composite plate with circular cutout. The Various sizes of centrally located square plate/skew plate with circular cutouts are considered in order to examine the effect of cutout size and boundary condition on the fundamental natural frequency of the square graphite epoxy laminate. The Natural frequencies of the finite element (FE) were analyzed by the ANSYS software, which was found by analysis.

Keywords: Circular Cutout; Model Analysis; Boundary Condition; Skew plate; FEM.

Introduction

Composite material is a made from any material of at least two different substances, just like concrete. Carbon plastic fiber reinforced combine high strength and stiffness of the fiber with low weight and tensile strength. Glass, wood and other types of fibers are used, and may be woven or the fibers laminate. Many composite materials as are produced such as reinforced fiber glass used for automobile bodies and boat hulls plastic, but the term is generally used to describe one of several modern industrially manufactured composites such as carbon plastics fiber reinforced. Materials allow mixing a compound of properties of the separate components.

Kant and Swaminathan [1] presented the static behavior of laminated composite and sandwich plates which are solved analytically using Navier's technique based on higher order refined theory. Zhang and Kim [2] presented geometrically nonlinear static responses of laminated composite plates by using two new displacement based quadrilateral plate (RDKQ-NL20 and RDKQ-NL24) elements. Akavci *et al.* [3] investigated the symmetrically laminated composite plates on elastic foundation in the framework of the FSDT. Attallah *et al*. [4] presented 3-D solutions of laminated composite plates by using a combined finite strip and state space approach. Krishna Murty and Vellaichamy [5] studied the suitability of the HSDT for the stress analysis of laminated composite panels based on cubic in plane displacements and parabolic normal displacements. Raju *et al*. [6] and [8] analyzed nonlinear static behavior of fibre reinforced plastic (FRP) laminates with circular cutout on the effect of thickness ratio and skew angle, respectively. Kant and Swaminathan [9] analyzed analytically the free vibration responses of laminated composite and sandwich plates based on a higher order refined theory and used Navier's technique to obtain the solution in closed form. Khdeir and Reddy [10] studied free vibration behavior of laminated composite plates using second order shear deformation theory and a generalized Levy type solution in conjunction with the state space concept. Reddy and Liu [11] presented Navier type exact solutions for bending and natural vibrations of laminated elastic cylindrical and spherical shells based on the HSDT. Reddy [12] studied the free vibration of anti-symmetric angle ply laminated plates including transverse shear deformation using FEM. Swaminathan and Patil [13] analyzed analytically the free vibration responses of anti-symmetric angle ply plates using a higher order refined computational model with twelve degree of freedom. Reddy and Phan [14] reported exact solutions of stability and vibration responses of isotropic and orthotropic simply supported plates according to the HSDT. Reddy and Kuppusamy [15] reported 3-D elasticity solutions natural vibrations of laminated anisotropic plates. Khdeir [15] investigated the free vibration of anti-symmetric angle ply laminated plates based on a generalized Levy type solution. This theory is a generalization of Mindlin's theory for isotropic plates to laminated anisotropic plates. Kant and Swaminathan [17] studied the free vibration behavior of isotropic, orthotropic and multilayer plates based on higher order refined theory. Srinivas *et al.* [18]

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

employed a three dimensional linear, small deformation theory for the free vibration analysis of simply supported homogeneous and laminated thick rectangular plates. Reddy [17] studied the large amplitude flexural vibration of layered composite plates with cutout based on a Reissner-Mindlin type of a shear deformable theory and employed the nonlinear strain displacement relations of the von-Karman theory. Sivakumar *et al.* [19] investigated the free vibration responses of composite plates with an elliptical cutout based on FSDT and using a genetic algorithm. Kumar and Shrivastava [20] employed a finite element formulation based on HSDT and Hamilton's principle to study the free vibration responses of thick square composite plates having a central rectangular cutout, with and without the presence of a delamination around the cutout. Krishna Reddy and Palaninathan [21] analyzed the free vibration responses of laminated skew plates using a general high precision triangular plate bending finite element.

Problem modeling

Square laminated plate with circular cutout

Various sizes of centrally located circular cutouts are considered in order to examine the effect of cutout size on the natural frequency of the square graphite epoxy laminate. The laminate has side to thickness ratio (a/h) of 100, lay-up sequence (0/90)s. The properties of each lamina are given in Table 1. The cutout ratio (i.e. d/a) along x-axis and y-axis is varied from 0.0 to 0.6 in steps of 0.2. Plate geometries for plates with cutout ratio 0.0, 0.2, 0.4, 0.6 are shown in Fig 1

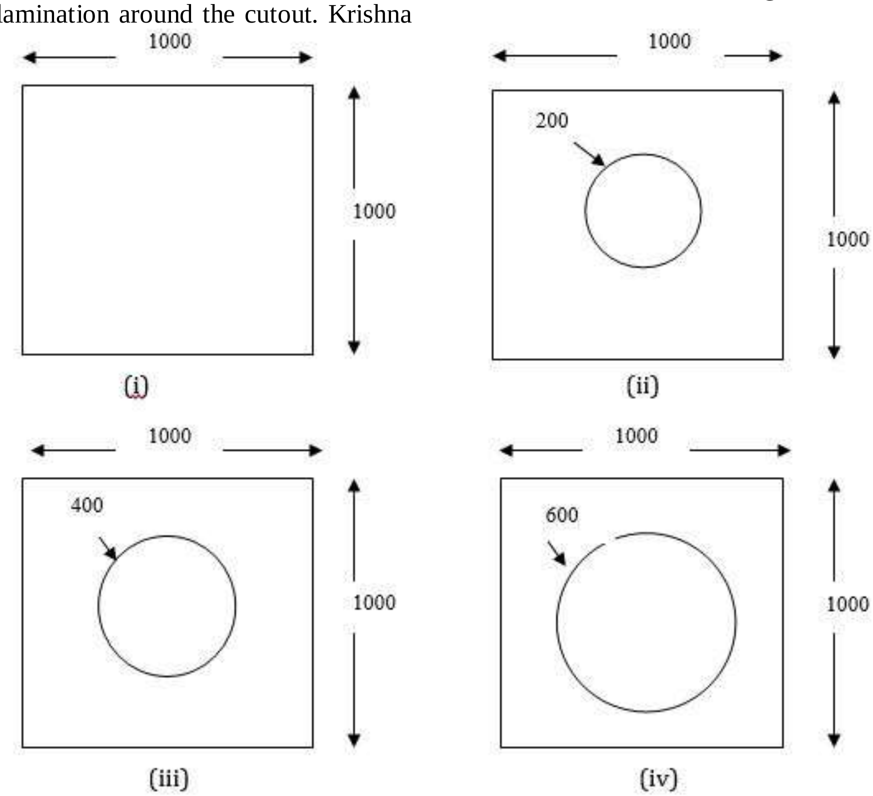


Figure 1: Plate geometry of laminated plate

1) Plate geometry with cutout ratio 0.
2) Plate geometry with cutout ratio 0.2.
3) Plate geometry with cutout ratio 0.4.
4) Plate geometry with cutout ratio 0.6.

Four types of boundary condition namely FFFC, FCFC, CCCC and SSSS (where F, C and S stand, respectively, for a free, a clamped, a simply supported edge) are considered in order to examine the effect of boundary condition on the fundamental natural frequency of a square graphite epoxy laminate with a centrally

locatecircular cutout. The FFFC, FFCC, FCFC, CCCC and SSSS stand for five types of boundary conditions as given below.

Table 1: Material properties of each lamina

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

Material Constant	E_x	E_y	E_z	G_{xy}	G_{yz}	G_{xz}	ν_{xy}	ν_{yz}	ν_{xz}	ρ
Values	137.90 GPa	14.48 GPa	14.48 GPa	5.86 GPa	5.86 GPa	5.86 GPa	0.21	0.21	0.21	1500 kg/m^3

Cutout ratio is varied from 0.0 to 0.6 in steps of 0.2. Plate geometries for plates with cutout ratio 0.0, 0.2, 0.4, 0.6, are shown in Figure 1. The laminate has side to thickness ratio of 100, and the properties of each lamina are given in Table 1. The lay-up sequence namely (0/90)s, is considered. Results are summarized in Table 2.

Table 2: Frequencies (Hz) for varying cutout size under different boundary conditions for square laminated plate with circular cutout and lay-up-sequence (0/90)s

Conditions	Modes	d/a Ratio			
		0	**0.2**	**0.4**	**0.6**
FFFC	1	14.631	9.5138	8.7034	7.2117
	2	19.54	9.5138	11.759	16.103
	3	54.766	48.595	47.921	45.34
	4	92.916	59.314	57.976	60.251
	5	98.873	62.318	61.215	64.197
FCFC	1	94.601	69.191	71.286	68.24
	2	96.795	71.835	72.54	69.17
	3	113.83	99.296	117.72	171.02
	4	174.73	168.57	145.09	171.54
	5	268.91	180.12	164.53	176.67
CCCC	1	108.16	111.87	147.59	263.64
	2	170.03	194.98	175.73	269.94
	3	276.28	202.9	185.67	271.34
	4	299.66	310.63	257.25	281.46
	5	311.28	362.78	304.97	385.14
SSSS	1	50.279	41.285	42.427	54.293
	2	101.68	115.79	89.662	88.57
	3	174.84	119.97	91.437	89.481
	4	204.05	190.5	166.1	145.29
	5	209.82	252.95	214.2	191.81

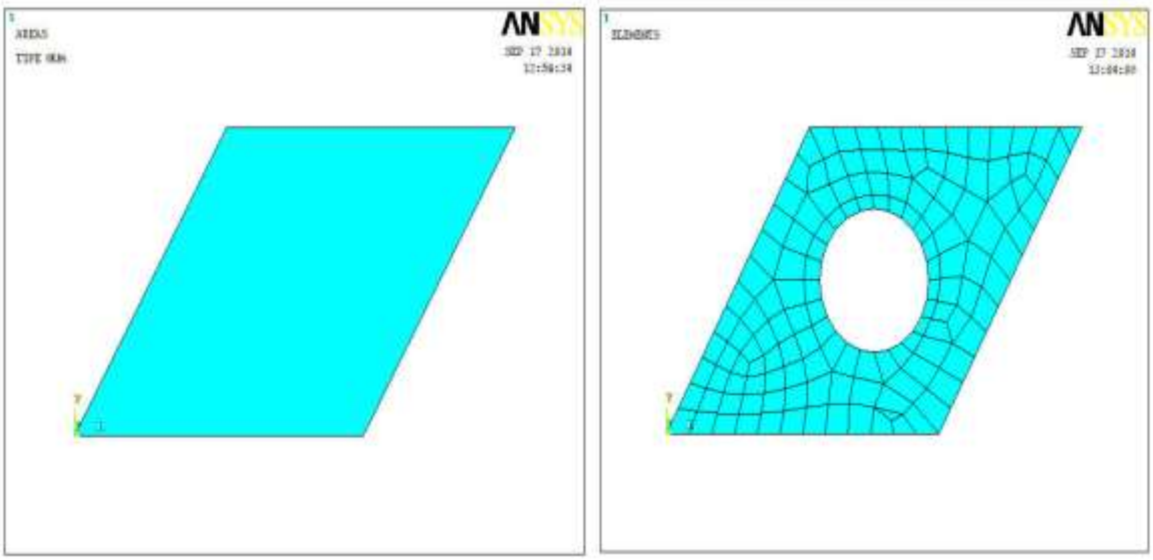
ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

Skew square laminated plate with circular cutout:
Various sizes of centrally located skew circular cutouts are considered in order to examine the effect of cutout size on the natural frequency of the square graphite epoxy laminate. The laminate has side to thickness ratio (a/h) of 100, lay-up sequence (0/90)s. The properties of each lamina are given in Table 1.

Table 1: Material properties of each lamina

Material Constant	E_x	E_y	E_z	G_{xy}	G_{yz}	G_{xz}	ν_{xy}	ν_{yz}	ν_{xz}	**ρ**
Values	137.90 GPa	14.48 GPa	14.48 GPa	5.86 GPa	5.86 GPa	5.86 GPa	0.21	0.21	0.21	1500 kg/m^3

The cutout ratio (i.e. a/s) along x-axis and y-axis is varied from 0.0 to 0.6 in steps of 0.2. The Finite Element Method of with cutout ratio 0.0, 0.2, 0.4, 0.6 are shown in Fig 2.



(i) ***(ii)***
Figure-2: (i) Plate geometry with cutout ratio 0, (ii) Plate geometry with cutout ratio 0.2

Table 3: Frequencies (Hz) for varying cutout size under different boundary conditions for skew (45^0) square laminated plate with circular cutout and lay-up-sequence (0/90)s

Conditions	**Modes**	**d/a Ratio**			
		0	**0.2**	**0.4**	**0.6**
FFFC	1	15.119	9.8209	8.4397	7.4875
	2	22.202	22.332	21.097	18.527
	3	64.322	57.759	56.615	54.197
	4	96.211	62.938	60.882	58.346
	5	116.84	99.307	101.33	92.845
FCFC	1	99.254	80.027	77.001	79.111
	2	104.66	83.749	87.829	81.821
	3	134.82	122.93	161.44	193.26

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

	4	214.42	191.3	181.82	206.83
	5	282.57	212.22	212.65	234.6
CCCC	1	126.33	139.45	207.05	325.27
	2	215.43	219.51	221.36	326.95
	3	307.88	259.03	293.09	644.23
	4	339.18	361.95	352.85	646.76
	5	425.59	448.65	405.95	742.24
SSSS	1	100.91	93.479	122.96	158.78
	2	156.66	155.22	143.74	170.66
	3	266.31	215.01	222.62	316.88
	4	270.37	266.53	274.66	325.07
	5	335.96	340.72	329.21	485.42

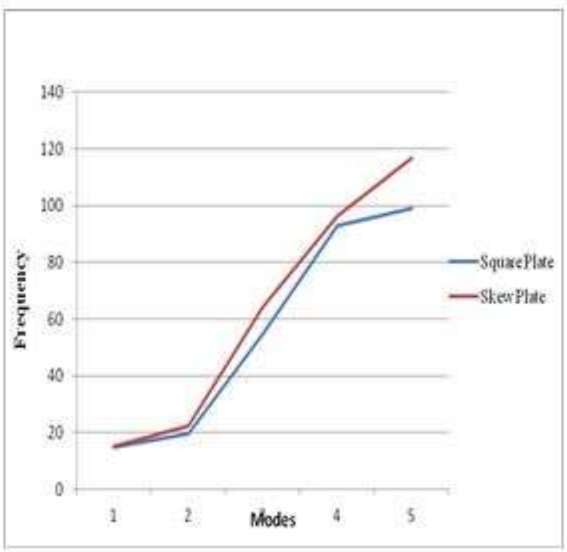


Figure 3.1: Graph between Frequency and Modes under FFFC boundary Conditions

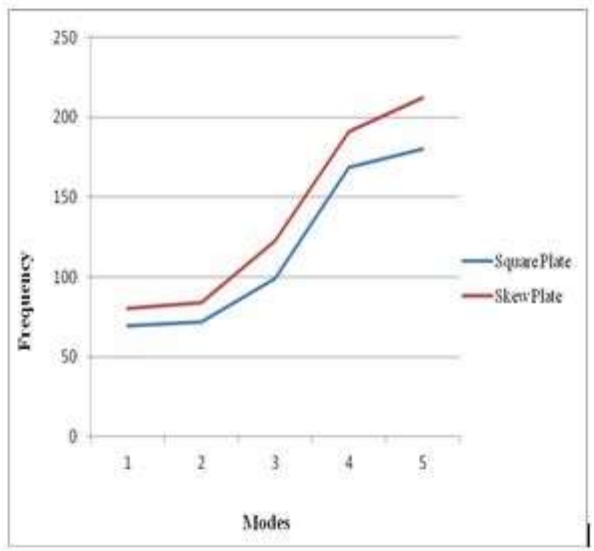


Figure 3.2: Graph between Frequency and Modes under FCFC boundary Conditions

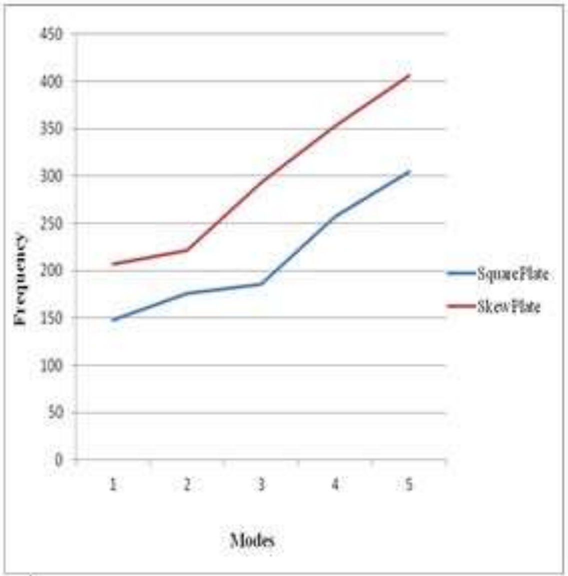


Figure 3.3: Graph between Frequency and Modes under CCCC boundary Conditions

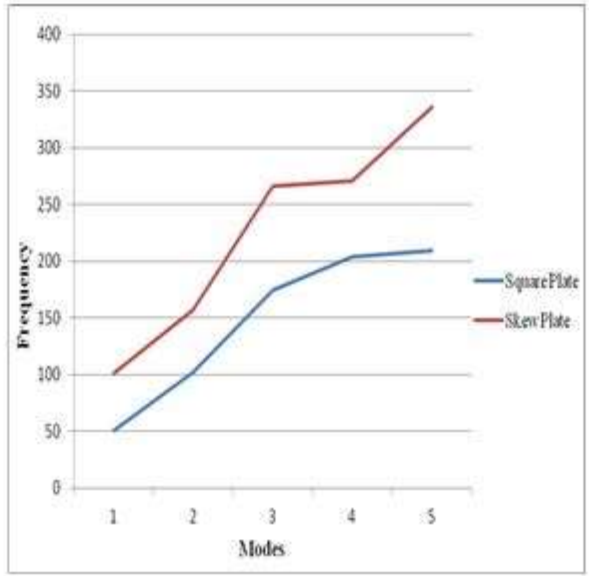


Figure 3.4: Graph between Frequency and Modes under SSSS (Case I) boundary Conditions

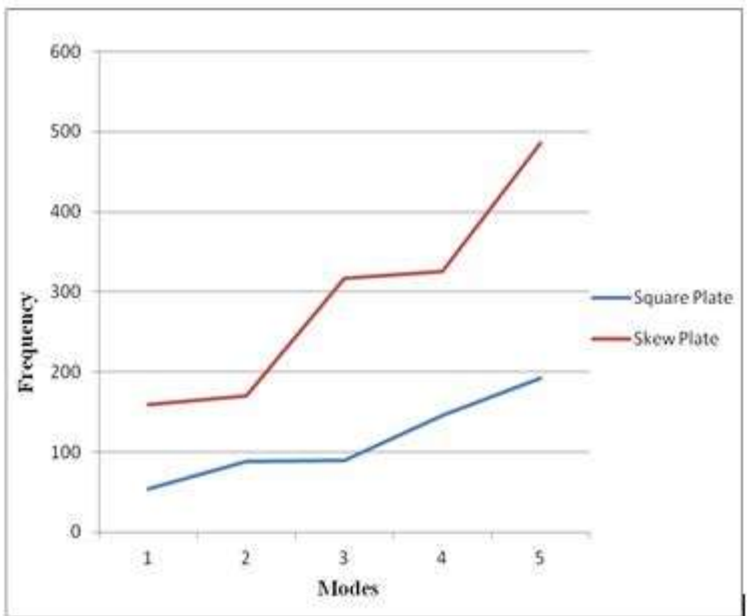


Figure 3.5: Graph between Frequency and Modes under SSSS (Case II) boundary Conditions

Result & discussion

Static Analysis of different boundary conditions for square laminated plate with lay-up-sequence (0/90)$_s$

In this example, four layers symmetric cross ply (0˚/90˚) s square plate with different boundary conditions length 1m and thickness 10 mm under uniformly distributed load is considered. The material properties and state support are taken from Table 6 for the numerical analysis. The central deflection obtained using the current model with different mesh size is drawn listed in Table 9 and 10.

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

Table 4: Maximum Deflections for different boundary conditions for square laminated plate with lay-up-sequence (0/90)s

Condition	**Load (N/m²)**		
	100	**300**	**500**
FFFC	1.22	3.67	6.115
FCFC	0.0256	0.0767	0.128
CCCC	0.0242	0.0725	0.121
SSSS	0.107	0.321	0.535

Table 5: Maximum Deflections for different boundary conditions for skew square laminated plate with lay-up-sequence (0/90)s

Condition	**Load (N/m²)**		
	100	**300**	**500**
FFFC	5.63	16.9	28.16
FCFC	0.066	0.2	0.333
CCCC	0.0178	0.0535	0.0892
SSSS	0.0387	0.116	0.194

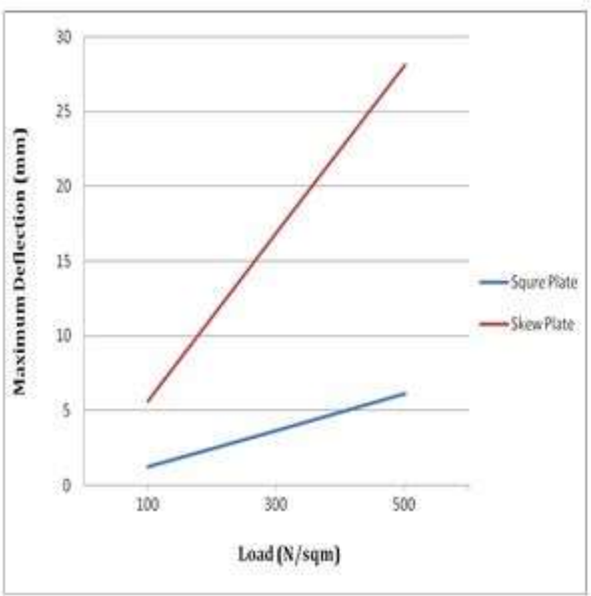


Figure 4.13: Graph between Maximum Deflection and Load under FFFC boundary Conditions

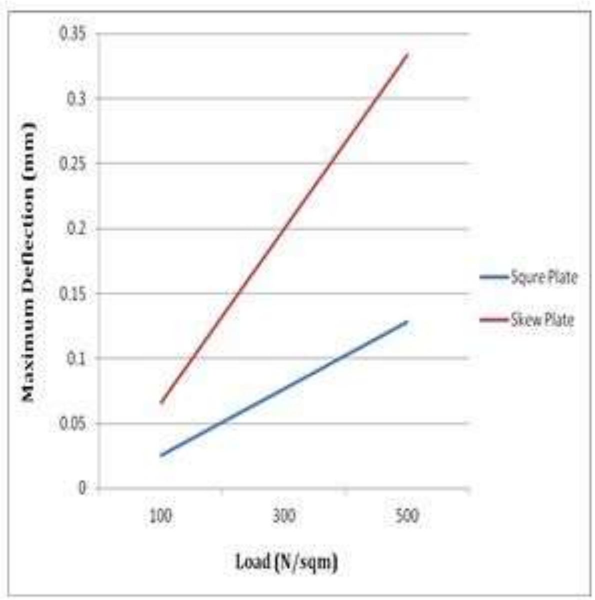


Figure 4.14: Graph between Maximum Deflection and Load under FCFC boundary Conditions

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

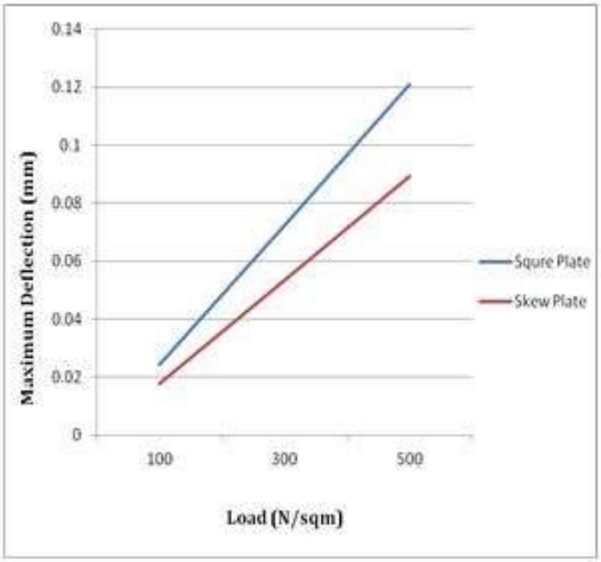


Figure 4.15: Graph between Maximum Deflection and Load under CCCC boundary Conditions

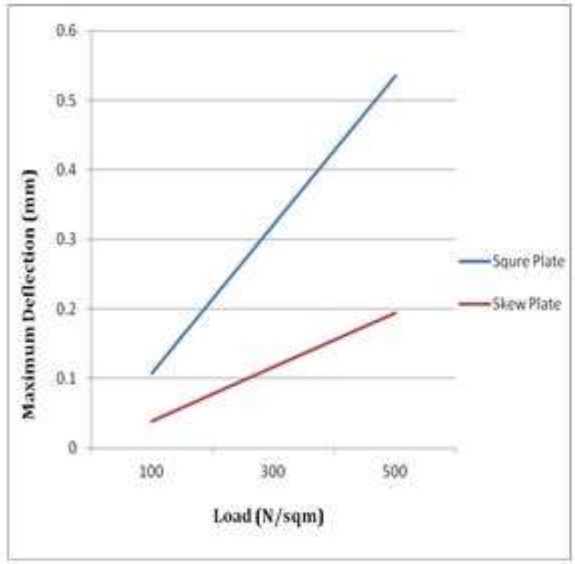


Figure 4.16: Graph between Maximum Deflection and Load under SSSS boundary Conditions

Conclusion

The finite element formulation is used to study effect of cutout on the free vibration of laminated composite plates. The formulation and program developed are general in nature and can handle cutout of any shape. The numerical results are presented and discussed in above. The broad conclusions that can be made from the present study are summarized as follows:

- The fundamental natural frequency changes only marginally if a small cutout (either of the two cutout ratios being small) is made in the plate. However, for intermediate and large size cutouts, the fundamental natural frequency increases rapidly; the amount of increase depends on cutout ratios in two directions.
- For square laminate with circular cutout, the natural frequency increases with the increasing constraint at the boundary irrespective of the size of the cutout. However, this increase is not uniform; it is also dependent on the particular mode of vibration.
- For square laminate with circular cutout, an increase in cutout size does not always result in an increase in the natural frequency. Besides depending on the cutout size, the increase or decrease also depends on the boundary condition.
- For square laminate with circular cutout, irrespective of modes of vibration natural frequency is more as compared to the Skew laminate with circular cutout.
- The natural frequency difference is found higher in SSSS boundary conditions for skew laminate with circular cutout as compared to boundary conditions for square laminate with circular cutout.
- For square laminate with circular cutout and skew laminated Circular cutout, the nature of the curves showing variation of fundamental natural frequency with cutout ratio depend on the boundary conditions.

Reference

[1]. Kant T. and Swaminathan K., Analytical solutions for the static analysis of laminated composite and sandwich plates based on a higher order refined theory, *Composite Structures*, vol.56 (2002): pp. 329-344.

[2]. Zhang Y.X. and Kim K.S., Geometrically nonlinear analysis of laminated composite plates by two new displacement based quadrilateral plate elements, Composite Structures, vol.72 (2006): pp. 301-310.

[3]. Akavci S.S., Yerli H.R. and Dogan A., The first order shear deformation theory for symmetrically laminated composite plates on elastic foundation, *The Arabian Journal for Science and Engineering*, vol.32, Oct.(2007): pp. 341-348.

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

[4]. Attallah K.M.Z., Ye J.Q. and Sheng H.Y., Three dimensional finite strip analysis of laminated panels, *Computers and Structures*, vol.85 (2007): pp. 1769–1781.

[5]. Krishna Murty A.V. and Vellaichamy S., On higher order shear deformation theory of laminated composite panels, *Composite Structures*, vol. 8 (1987): pp. 247-270.

[6]. Raju V. V., Bala Krishna Murthy V., Suresh Kumar J. and Vijaya Kumar Reddy K., Effect of thickness ratio on nonlinear static behaviour of skew bidirectional FRP laminates with circular cutout, *International Journal of Applied Engineering Research*, 1 (2011): pp. 923-932.

[7]. Raju V. V., Krishna Murthy V. and Suresh Kumar J., Effect of skew angle on nonlinear static behavior of fibre reinforced plastic (FRP) laminates with circular cutout, *International Journal of the Physical Sciences*, vol.6, Nov.(2011): pp. 7119-7124.

[8]. Kant T. and Swaminathan K., Analytical solutions for free vibration analysis of laminated composite and sandwich plates based on a higher order refined theory, *Composite Structures*, vol.53, (2001): pp. 73-85.

[9]. Khdeir A.A. and Reddy J.N., Free vibrations of laminated composite plates using second order shear deformation theory, *Computers and Structures*, vol.71, June (1999): pp. 617-626.

[10]. Reddy J.N. and Liu C.F., A higher order shear deformation theory of laminated elastic shells, *International Journal Engg Sci*, vol.23 (1985): pp. 319-330.

[11]. Reddy J.N., Free vibration of anti-symmetric, angle ply laminated plates including transverse shear deformation by the finite element method, *Journal of Sound and Vibration*, vol.66, Oct. (1979): pp. 565-576.

[12]. Swaminathan K. and Patil S.S., Analytical solutions using a higher order refined computational model with 12 degrees of freedom for the free vibration analysis of anti-symmetric angle ply plates, *Composite Structures*, vol.82, Jan.(2008): pp. 209-216.

[13]. Reddy J.N. and Phan N.D., Stability and vibration of isotropic, orthotropic and laminated plates according to a higher order shear deformation theory, *Journal of Sound and Vibration*, vol.98, May (1985): pp. 157-170.

[14]. Reddy J.N. and Kuppusamy T., Natural vibrations of laminated anisotropic plates, *Journal of Sound and Vibration*, vol.94 (1984): pp. 63-69.

[15]. Khdeir A.A., Free vibration of anti-symmetric angle ply laminated plates including various boundary conditions, *Journal of Sound and Vibration*, vol.122, April (1988): pp. 377-388.

[16]. Kant T. and Swaminathan K., Free vibration of isotropic, orthotropic and multilayer plates based on higher order refined theories, *Journal of Sound and Vibration*, vol.241, March (2001): pp. 319-327.

[17]. Srinivas S., Rao C.V. and Rao A.K., An exact analysis for vibration of simply supported homogeneous and laminated thick rectangular plates, *Journal of Sound and Vibration*, vol.12, June (1970): pp. 187-199.

[18]. Reddy J.N., Large amplitude flexural vibration of layered composite plates with cutouts, *Journal of Sound and Vibration*, vol.83, (1982): pp. 1-10.

[19]. Sivakumar K., Iyengar N.G.R. and Deb K., Optimum design of laminated composite plates with cutouts using a genetic algorithm, *Composite Structures*, vol.42, July (1998): pp. 265-279.

[20]. Kumar A. and Shrivastava R.P., Free vibration of square laminates with delamination around a central cutout using HSDT, *Composite Structures*, vol.70, Sept. (2005): pp. 317-333.

[21]. Krishna Reddy A.R. and Palaninathan R., Free vibration of skew laminates, *Computers and Structures*, vol.70, Feb. (1999): pp. 415-423.