International Journal of Scientific Research & Engineering Trends
Volume 6, Issue 3, May-June-2020, ISSN (Online): 2395-566X

Free Vibration Analysis of Laminated Composite Plate with a Central Hole

M.Tech.Scholar Rahul Patel, Professor Dr. Rakesh Patel
Department of Civil Engineering, SIRTS, Bhopal

Abstract – **In this investigation free vibration analysis of a composite plate is presented. An orthotropic plate with symmetric fibre orientation was considered for this study. The material propertieswere fixed. The natural frequencies were computed for different boundary conditions, hole-shape, aspect ratio, and fibre orientation.The effect of these variables on the nature of vibration is analysed and discussed. Also, the natural frequencies of a laminated composite plate with holes of various sizes were considered in order to examine the effect on the fundamental natural frequency. The eight nodedshell 281 was used throughout the analysis. ANSYS 15.0 is used for modelling and analysis of the laminated plates. The Natural frequencies of the finite element (FE) were analysed by the ANSYS software.**

Keywords- Free vibration, laminated composite plate, Finite Element Analysis, Lamination angles

I. INTRODUCTION

Plates are straight, flat and non-curved surface structures whose thickness is slight compared to their other dimensions. Generally plates are subjected to load conditions that cause deflections transverse to the plate. Geometrically they are bound either by straight or curved lines. Plates have free, simply supported or fixed boundary conditions. The static or dynamic loads carried by plates are predominantly perpendicular to the plate surface. The load carrying action of plates resembles that of beams or cables to a certain extent. Hence plates can be approximated by a grid work of beams or by a network of cables, depending on the flexural rigidity of the structures. Plates are of wide use in engineering industry. Many structures such as ships and containers require complete enclosure of plates without use of additional covering which consequently saves the material and labour.

II. LITERATURE SURVEY

B. Vishnuchaitanyaet. al. (2017) studied the effects of the variations of behaviour for different shape of holes by maintaining same length/height ratio and hole area ratio are studied. Scope of this project is to find out the best location of the holes. The ANSYS software is used for analysing the plates under different boundary conditions and different orientation of laminate. Eight-noded Shell 99 is used throughout the analysis which is a linear element. Two different boundary conditions are considered those are CFFF (clamped free free free) and CFCF-(clamped free clamped free) conditions and length to height ratio considered are 50 and 200.The hole area ratio is maintained as constant throughout the analysis as 0.04.Two different layers of laminate is considered those are 4 no's and 8 no's having six different orientations each.

R. N. Mokalet. al. (2017) studied a consistent polynomial shear deformation theory is presented for the free vibration of thick isotropic square and rectangular plate. In this displacement based theory, the in-plane displacement field use parabolic function in terms of thickness coordinate to include the shear deformation effect. Governing equations and boundary conditions of the theory are obtained using the principle of virtual work. Results of frequency are obtained from free vibration of simply supported isotropic square and rectangular plates and compared with those of other refined theories and frequencies from exact theory.

Madhusudan Reddy K et. al. (2016) studied the Vibration characteristics of jute fabric reinforced hybrid polymer matrix composites. These fibers are reinforced in The Hybrid polymer resin of combination of 15% Cashew Nut Shell Liquid (CNSL) and polyester resin. An experimental modal testhas been conducted on samples to get the natural frequency, damping and mode shape. Experimental values have been verified with the computational numerical model developed by using FEM package ANSYS and the natural frequency of jute fabric hybrid polymer matrix composite is determined under fixed condition.

Beena S, Aiswarya S (2016) studied the dynamic analysis of laminated carbon composite and find out the best shape of the holes. The ANSYS software is used for analysing the plates.

K. Sai Vivek (2016) studied the free vibration of skew laminated composite plates with circular cutout is investigated by using finite element method based on a first order shear deformation theory with the help of ANSYS 14.5 – a commercial finite element program. The analysis was carried out by using eight nodedisoparametric shell element. Simply supported and clamped boundary conditions are considered. The results are presented for 15º and 30º skew laminated composite plates with circular cutout. The effects of numberof plies, boundary conditions, side to thickness ratios and skew angles on free vibration behaviour of cross-ply and angle-ply plates are discussed

.

K. Maithry, B D V Chandra Mohan Rao (2015) investigated the dynamic response of laminated composite plates to excitations, varying arbitrarily with time. Rectangular laminated plates fixed along the edges with holes at different positions are investigated by maintaining the same length / height ratio and hole area ratio for different fiber orientations. The modelling and dynamic analysis of the laminated plates has been carried out using ANSYS 13.0 software. The most robust fiber orientation with respect to various response parameters is suggested.

Deepanshu Bhatt, Yogesh Mishra and Dr. P.K. Sharma (2014) present an experimental study 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 toexamine 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.

Kanak Kalitaet. al. (2013) investigated the problem of reduction of principal stresses by placing symmetric auxiliary holes around the central square cutout in an orthotropic plate is studied. Small auxiliary holes are preferred for the study since it would involve removal of minimal area from the orthotropic plate. Effect of the distance of the auxiliary holes from the central cutout on stress mitigation is studied. Since analytical treatment of this kind of problem is difficult, a popular finite element package ANSYS is used for the analysis. Results for orthotropic plates with all edges fixed are presented here in graphical form.

III. METHODOLOGY

An attempt has been made to study the free vibration characteristics of square laminated composite plates with different cut-out shapes. For simplification of the analysis, the plate is assumed to be orthotropic and symmetric with respect to the mid-plane. The effect of boundary conditions, hole size, cutout ratio, and fiber orientation on the natural frequencies of vibration is studied.

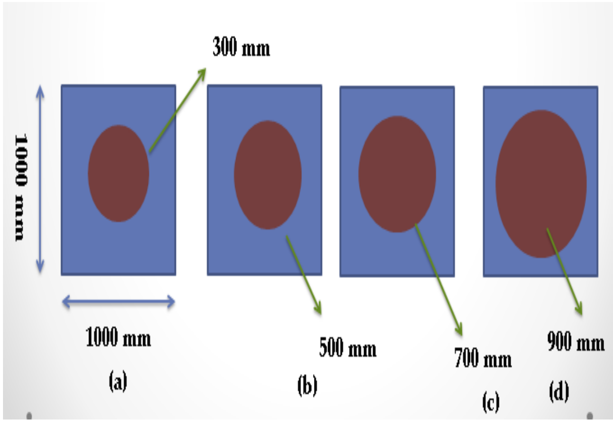

Fig. 1 Different cases with different cutout size

.

First, a single circular hole at the center is considered and then the analysis is further extended to different sizes of cutout at the center of the plate. All the calculations have been done with the finite element package ANSYS 15.0.

IV. OBJECTIVE OF STUDY

The main objectives of the present study are
1. The natural frequencies were computed for different boundary conditions (FFFC, FCFC, CCCC and SSSS),
2. Hole size,
3. Aspect ratio,
4. Fber orientation.

The effect of these variables on the nature of vibration is analysed and discussed. ANSYS 15.0 is used for the computation of natural frequencies.

V. MODELLING USING ANSYS 15.0

ANSYS (acronym for Analysis System) is a general purpose Finite Element Analysis (FEA) program that solves a vast area of solid and structural mechanics problems in geometrically complicated regions. In the present work, ANSYS 15.0 is used to model the plate, to compute natural frequencies and to plot deformed shapes. ANSYS is finite element based software which gives good results on analysis of any structural elements. It has the capability to analyze multilayer laminated composite with different orientation. SHELL 281 is used as a modeling element as shown in Fig.2.

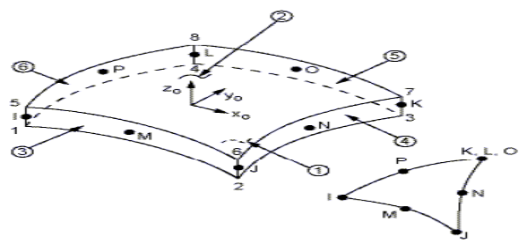

Fig. 2: A SHELL 281 Element .

VI. MATERIAL PROPERTIES

These Composite materials are used different engineering applications and manufacture industries. Now a day's most probability of economic progress is very high because composite material is rapidly use in many industries just like civil, marine, aeronautical and mechanical engineering applications. The materials chosen to make this work are graphite-epoxy.

Table 1 Material properties of each lamina

Material Constant	Ex	Ey	Ez	Gxy	Gyz	Gxz	υxy	υyz	υxz	ρ
Values	172.72 GPa	6.909 GPa	6.909 GPa	3.45 GPa	3.45 GPa	1.38 GPa	0.25	0.25	0.25	1500 Kg/m3

VII. RESULTS AND DISCUSSIONS

A laminated composite plate with a central circular hole is considered and the natural frequencies are computed. Also, the effect of boundary conditions, cut out ratio, hole size and fiber orientation on the free vibration characteristics is analysed. The results are presented through following sub-sections.

1. Effect of Boundary Conditions

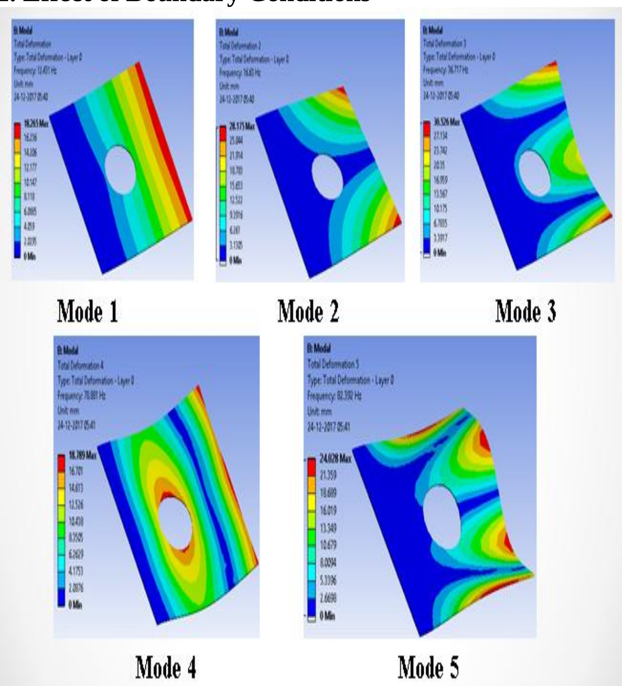

Fig 4: Mode shapes for a square cross-ply (0°/90°/0°) plate with a central circular hole for the boundary condition CFFF with cut-out ratio 0.3

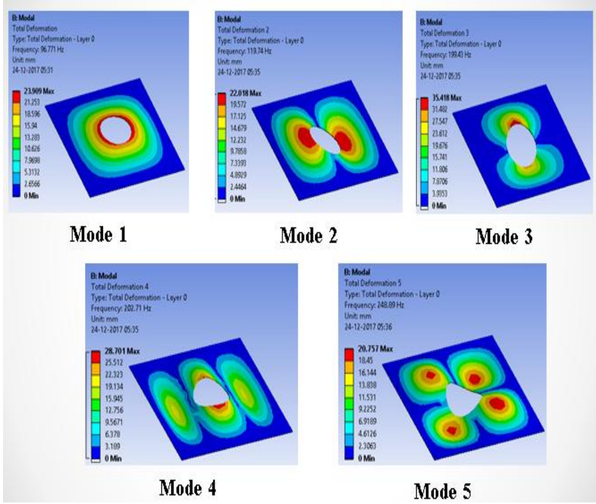

Fig 5: Mode shapes for a square cross-ply (0°/90°/0°) plate with a central circular hole for the boundary condition CCCC with cut-out ratio 0.3

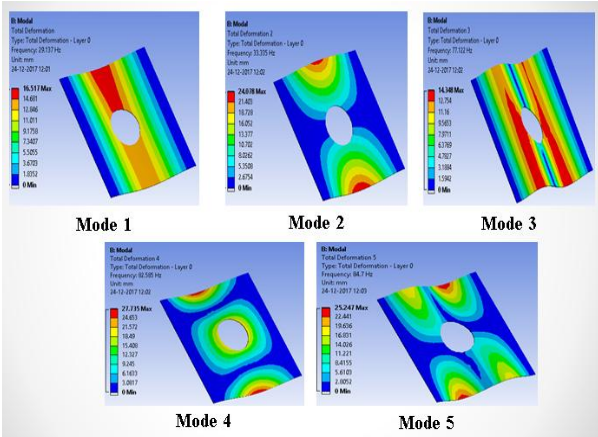

Fig 6: Mode shapes for a square cross-ply (0°/90°/0°) plate with a central circular hole for the boundary condition FCFC with cut-out ratio 0.3.

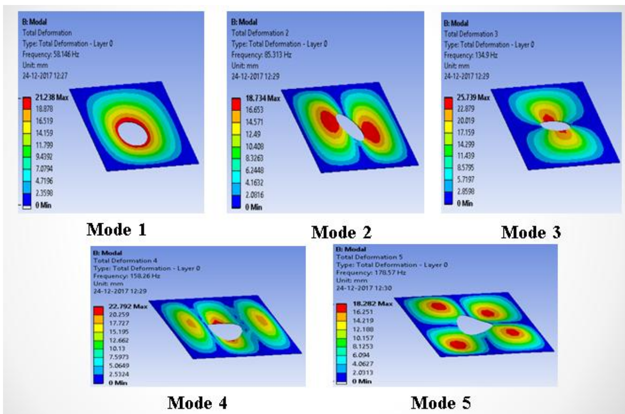

Fig 7: Mode shapes for a square cross-ply (0°/90°/0°) plate with a central circular hole for the boundary condition SSSS with cut-out ratio 0.3

International Journal of Scientific Research & Engineering Trends
Volume 6, Issue 3, May-June-2020, ISSN (Online): 2395-566X

Table 2 First five natural frequencies (Hz) for a square cross-ply (0°/90°/0°) with central circular hole for four different boundary conditions with cut-out ratio 0.3

Mode Number	Cut out ratio= 0.3			
	Boundary Condition			
	CFFF	CCCC	FCFC	SSSS
1	12.43	96.77	29.13	58.14
2	16.63	119.74	33.33	85.31
3	36.71	199.43	77.12	134.9
4	78.88	202.71	82.58	158.26
5	82.39	248.89	84.7	178.57

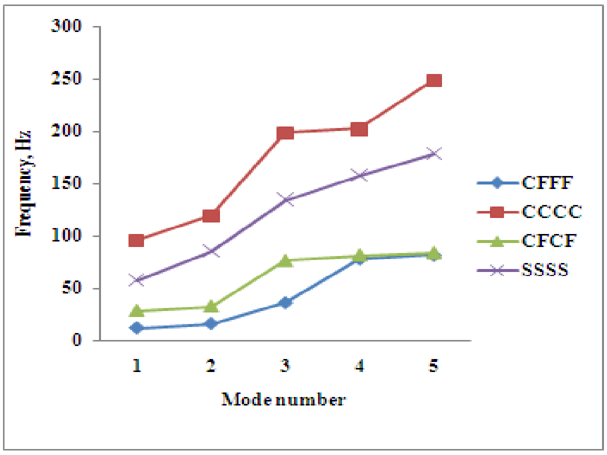

Fig. 8: Variation of natural frequencies (Hz) for a square cross-ply plate with central circular hole for four different boundary conditions with cut-out ratio 0.3.

From the above table, it can be observed that the natural frequency of vibration is highest for CCCC plate, whereas it is lowest for CFFF plate. FCFC plates show intermediate values.

2. Effect of Hole- Size & Cut-Out Ratio

Table 1: First five natural frequencies (Hz) for a square cross-ply (0°/90°/0°) with central circular hole for four different boundary conditions with cut-out ratio 0.5

Mode Number	Cut out ratio= 0.5			
	Boundary Condition			
	CFFF	CCCC	FCFC	SSSS
1	11.22	129.49	85.59	62.68
2	16.06	133.26	85.75	84.80
3	35.47	207.25	129.85	106.51
4	80.12	233.23	134.52	158.87
5	80.39	250.72	206.38	160.97

From the above table, it can be observed that the natural frequency of vibration is highest for CCCC plate, whereas it is lowest for CFFF plate. SSSS plates show intermediate values.

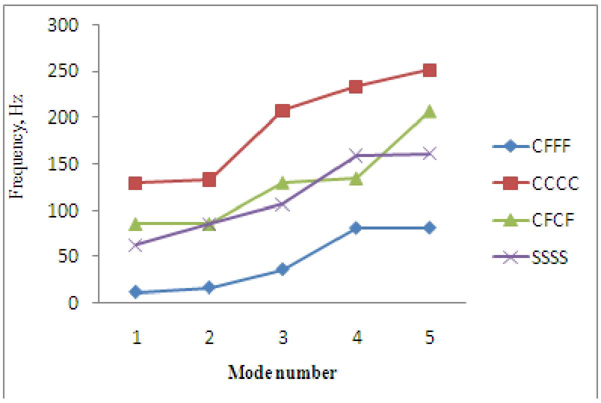

Fig. 9 Variation of natural frequencies (Hz) for a square cross-ply plate with central circular hole for four different boundary conditions with cut-out ratio 0.5

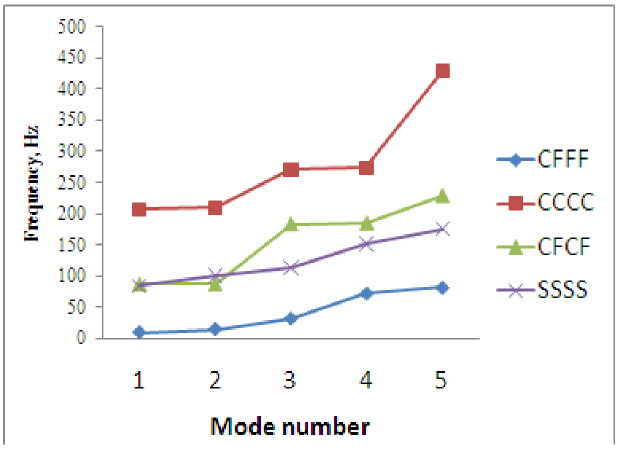

Fig. 10 Variation of natural frequencies (Hz) for a square cross-ply plate with central circular hole for four different boundary conditions with cut-out ratio 0.7

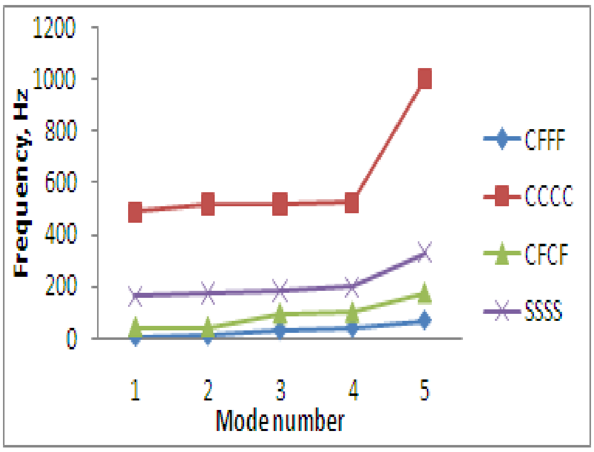

Fig. 11 Variation of natural frequencies (Hz) for a square cross-ply plate with central circular hole for four different boundary conditions with cut-out ratio 0.9

International Journal of Scientific Research & Engineering Trends
Volume 6, Issue 3, May-June-2020, ISSN (Online): 2395-566X

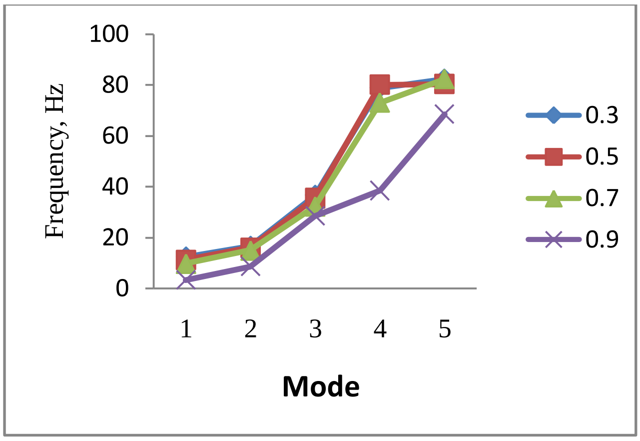

Fig.12 Variation in natural frequencies (Hz) for CFFF square cross ply (0°/90°/0°) plate with varying cut-out ratio

It can be concluded that the increase in hole-size, the frequency decreases for the five mode of vibration in CFFF boundary condition.

3. Effect of Fiber-Orientation

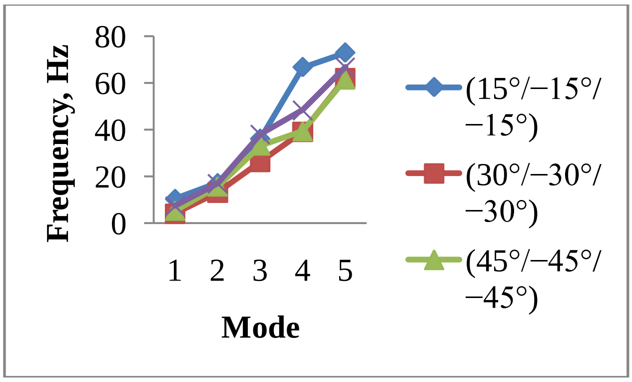

Fig.12 Variation in natural frequencies (Hz) for CFFF square cross ply plate with varying fiber orientation

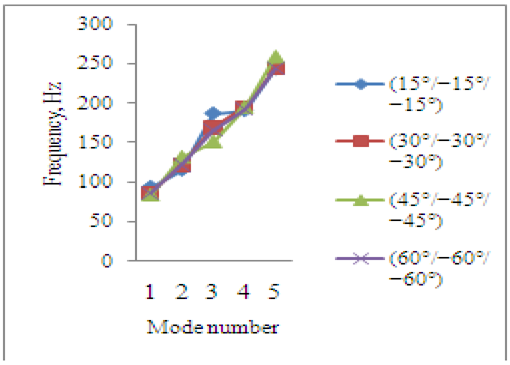

Fig.13 Variation in natural frequencies (Hz) for CFFF square cross ply plate with varying fiber orientation

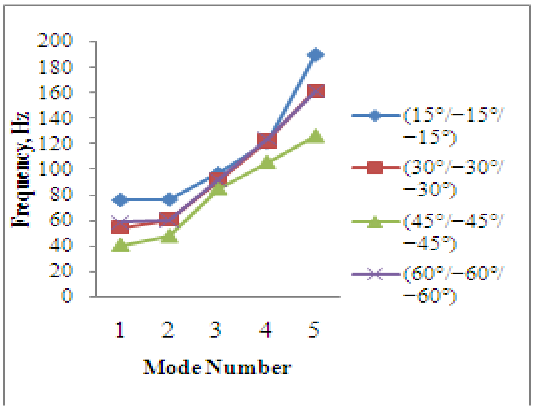

Fig. 14 Variation in natural frequencies (Hz) for CCCC square cross ply plate with varying fiber orientation

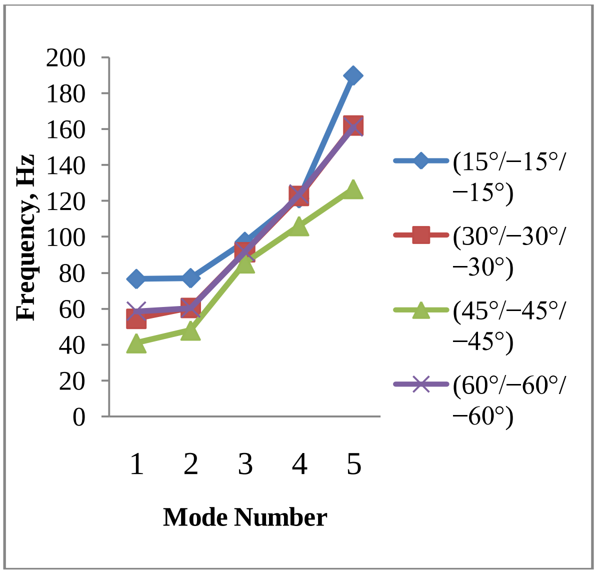

Fig 15 Variation in natural frequencies (Hz) for FCFC square cross ply plate with varying fiber orientation

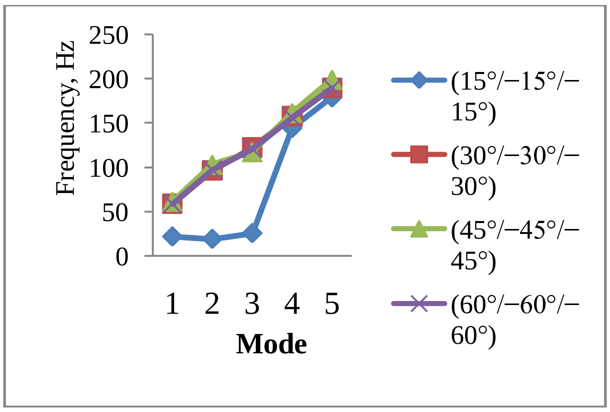

Fig 45: Variation in natural frequencies (Hz) for SSSS square cross ply plate with varying fiber orientation

International Journal of Scientific Research & Engineering Trends
Volume 6, Issue 3, May-June-2020, ISSN (Online): 2395-566X

VIII. CONCLUSION

The free vibration of a laminated composite plate is analysed for different boundary conditions, different number of layers, hole-size, aspect ratio, fiber-orientation and hole shape.

1. Effect of Boundary Conditions

It can be observed that the natural frequency of vibration is highest for CCCC plate, whereas it is lowest for CFFF plate. FCFC plates show intermediate values.

2. Effect of Hole size & Cut-out ratio

1. It can be concluded that the increase in hole-size, the frequency decreases for the five mode of vibration in CFFF boundary condition.
2. It can be concluded that the increase in hole-size, the frequency increases for the five mode of vibration for CCCC boundary condition.
3. It can be concluded that the increase in hole-size, the frequency increases till 0.7 cut-out ratio and after frequency decreases for the five mode of vibration for FCFC boundary condition.
4. It can be concluded that the increase in hole-size, the frequency increases for the five mode of vibration for SSSS boundary condition.

3. Effect of fiber orientation

It can be observed that the fundamental frequency of vibration increases with increase in angle of orientation of fibers.

REFERENCES

1. Sharma K Avadesh, Mittal N.D., “Review on stress and vibration analysis of composite plates”, Journal of applied sciences, Vol. 7 Issue 5, PP: 3156-3166.
2. Mishra Itishree, Kumar SahuShishir, “An Experimental Approach to Free Vibration Response of Woven Fiber Composite Plates under Free-Free Boundary Condition”, International Journal of Advanced Technology in Civil Engineering, Vol.1 Issue 2, PP: 67-72.
3. Kanak Kalita, Abhik Kumar Banerjee, SalilHaldar, “An Analysis to Mitigate Induced Stresses in Orthotropic Plates with Central Square Cut-out”, International Journal of Engineering Research and Technology, Volume 6, Number 3 , pp. 379-386.
4. Pushpendra k. kushwaha, jyotivimal, “Study of Vibration Analysis of Laminated Composite Plates Using FEM” International Journal of Advanced Mechanical Engineering, Vol. 4 Issue 4, PP: 675-680.
5. Sharma P.K, Mishra Yogesh, Deepanshu Bhatt Deepanshu, “Model analysis of Centre circular laminated composite plate with circular cutout”, International Journal of Advance Engineering and Research Development, Vol. 3, Issue 1, PP: 25-29.
6. Song Xiang, Chun Lu, Ji Wang, Wei-ping Zhao, “Free vibration of laminated composite plates by the various shear deformation theories”, 3rd International Conference on Material, Mechanical and Manufacturing Engineering, PP: 1948-1951.
7. PingulkarPushparaj and B. Suresha, “Free Vibration Analysis of Laminated Composite Plates Using Finite Element Method” Polymers & Polymer Composites, Vol. 24, No. 7, PP: 529-538.
8. Vivek K. Sai, “Free Vibration of Skew Laminated Composite Plates with Circular Cutout by Finite Element Method”, International Journal of Modern Engineering research, Vol. 6, Issue 6, PP: 15-23.
9. Vishnuchaitanya B., Rao K. V. N. Mallikharjuna, Pradeep Sai P.,” Dynamic Analysis of Laminated Composite Plates with Holes”, International Journal of innovative -technologies, Vol.5 Issue 4, PP: 618-622.
10. Reddy K Madhusudan, B. Vignesh, Venkatachalam G., “Investigations on Dynamic Analysis Of Jute Fabric Reinforced Hybrid Polymer Matrix Composites”, International Journal of Research in Science and Technology, Vol. 6, Issue 3, PP: 139-144.
11. K. Maithry, B D V Chandra Mohan Rao, “Dynamic Analysis Of Laminated Composite Plates”, International Journal of Research in Engineering and Technology, Volume: 04 Special Issue: 13, PP: 116-121.