FREE VIBRATION OF LAMINATED COMPOSITE PLATES WITH CUT-OUT RATIO (D/D RATIO) MODIFICATION UNDER (CFFF) AND (SFSF) BOUNDARY CONDITIONS

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ABSTRACT: This present paper deals with combined numerical and experimental approach on dynamics characteristics of laminated composite plate with square cut-outs. The laminated composite plates are made by using hand lay-up method. Bidirectional glass fibres are used as reinforcement and polyester resin as matrix for composite plate. The experimental dynamics test has been carried out by using different dimensions of plate with various design parameters such as cut out ratio (D/d ratio), position of cut out, aspect ratio (a/b ratio), no of layers, ply orientations under different boundary conditions. The natural frequencies of composite plate with cut-outs are determined numerically using ANSYS 14.5 software. The convergence study is done for numerically obtained results and compare with other existing literature. The experimental values are also compared with the result obtained from ANSYS 14.5 software. It was seen that the fundamental frequency decreases with increase the cut-out ratio (d/D ratio) under CFFF and SFSF boundary conditions. But fundamental frequency decreases with increase the cut-out ratio (d/D ratio) up to 0.2 under CFCF boundary condition. Further fundamental frequency increases on increase of cut-out ratio (d/D ratio).

KEYWORDS: Natural frequency, Laminated composite plate, Bi-directional glass fibre, Square cut-outs.

I. INTRODUCTION

Composite materials are structural materials which are obtained by combination of two or more different constituents on a macroscopic scale. There are two phases of composite such as reinforcing phase and matrix phase. The materials of reinforcing phase are in the form of fibres, particles or flakes and embedded in the matrix phase. The reinforcing material and the matrix material can be metal, ceramic, or polymer. The properties of composite materials are derived from its constituents, geometry and distributions of phases. Some of the composite materials such as plywood and reinforced concrete are being used for a long time. In general, composite materials may be fibrous, laminated and particulate. The composite materials inherit the superior qualities of the combining materials such as excellent high strength to weight ratio, high stiffness to weight ratio, low weight, long fatigue life, resistance to corrosion, good thermal conductivity and low specific density. So that fibre reinforced laminated are being increasing extensively in many engineering application. The elements such as plates and shell have been successfully implementation in real structures. For designers and engineers composites act as a solution for structural problems such as crack prevention.

IMPORTANCE OF CUT-OUT

Cut-out is used almost every structural element such as civil, aerospace and automotive industry. In aircraft components cut-outs are used to reduce the weight, to lay fuel lines and electrical lines etc. For doors and windows, cut-outs are provided in structure. In water retaining structure cut-outs are provided at the bottom of the structure for passage of liquid. Cut-outs are also needed for ventilation. Cut-outs in plate change the dynamics characteristics of plates. Sometimes designers use the cut-outs of different shapes and sizes to alter the natural frequency of the structure to make them safe. Most of the structures such as beams, columns and plates fail due to vibration. Hence vibration analysis of laminated composite plate with cut-out has been a major concern for designers and researcher etc.

II. OBJECTIVE AND SCOPE

From the above review of literature it is noted that most of the work done on laminated composite plates are analytical based on central cut-out. Almost all works are related to unidirectional fibre for fabrication of laminated composite. But now a day"s woven glass fibre are used for fabrication of laminated composite plates. The present work deals with an experimental investigation on vibration analysis of laminated composite plate with cut-out by considering the effect of cut-out ratio (d/D ratio), position of cut-out, aspect ratio (a/b ratio), ply orientation, no of layers under different boundary conditions. The results obtained from experimental works are compared with computational package ANSYS.

RESULT ANALYSIS

Free vibration analysis of laminated composite plate with cut-outs is analytically studied by using ANSYS software. The effect of different parameters such as aspect ratio (a/b), position of cut-out, no of layers, orientation and cut-out ratio(d/D) under different boundary conditions. The experimental results on free vibration of laminated plate with cut -outs are verified with numerically using ANSYS. Vibration analysis of this study is presented as following

- Comparison with previous results.
- Experimental and numerical results.

MODAL ANALYSIS

Cut-out may influence the dynamic behaviours of laminated composite structures. That‟s why in this present study, natural frequencies of composite plate with cut out are calculated both numerically and experimental programme. The effects of different parameters such as cut-out ratio (d/D ratio), no of layers, position of cut-out, aspect ratio (a/b ratio), different boundary condition and ply orientation on natural frequency of square cut-out plate were studied. The numerical results of modal analysis are compared with other existing literature.

COMPARISON WITH PREVIOUS RESULTS

Vibrational analysis of laminated composite plate with cut-out is computed numerically by finite element package ANSYS which are mentioned in previous chapter. The natural frequencies of laminated composite plates with two different end conditions such as SSSS (four edges of plate are simply supported) and CCCC (four edges of plate are clamped) are compared between the present numerical results with existing literature by Ju *et al.* (1995).

Table 5: Comparison of natural frequency (Hz) for glass epoxy laminated composite plates at different boundary condition

Material properties and geometry properties:

Ply orientation = (0/90/45/90/90/45/90/0), Density=1446.20 kg/m^3, E_{11} =132GPa, E_{22}= 5.35GPa, G_{12}=2.79GPa, $\upsilon_{12}=\upsilon_{13}=\upsilon_{23}$=0.29.

Length=0.25m, width=0.25m, thickness=0.00212m

Boundary condition	No of mode	Ju *et al.* (1995)	Present ANSYS
CCCC	1st	346.59	342.52
	2nd	651.51	634.36
	3rd	781.06	766.52
	4th	1017.20	961.62
SSSS	1st	164.37	163.33
	2nd	404.38	400.12
	3rd	492.29	493.74
	4th	658.40	835.39

Similarly dynamics analysis of laminated composite plate with central cut-outs based on present ANSY modelling is compared with Sharma *et al* (2014).There are four different boundary condition such as FFFC, FCFC, CCCC and SSSS are considered to examine the influence of end conditions on natural frequencies of a square laminated composite plate with circular cut-out at centre.Material properties and geometry properties of composite plate:

Length=1m, Width=1m, Cut-out ratio (diameter/side of square plate) = 0, 0.2, 0.4, 0.6, side to thickness ratio=100, Ply orientation = (0/90)s, E_{11}=137.20GPa, $E_{22}=E_{33}$=14.48GPa,$G_{12}=G_{13}=G_{23}$=5.86GPa,

$\upsilon_{12}=\upsilon_{13}=\upsilon_{23}$=0.21, Density=1500kg/m^3

Table 6: Natural Frequencies (Hz) of cut-out ratio=0.6 under different boundary conditions for square laminated composite plate with circular cut-out

Boundary condition	No of mode	Cut-out ratio	Sharma *et al* (2014)	Present ANSYS
FFFC	1st	0.6	7.21	6.99
	2nd		16.103	16.057
	3rd		45.34	45.277
	4th		60.251	59.793
	5th		64.197	64.973
FCFC	1st	0.6	68.24	65.066
	2nd		69.17	66.344
	3rd		171.02	156.30
	4th		171.54	158.44
	5th		176.67	167.58
CCCC	1st	0.6	263.64	232.97
	2nd		269.94	240.32
	3rd		271.34	244.68
	4th		281.46	253.27
	5th		385.14	345.35
SSSS	1st	0.6	54.293	52.976
	2nd		88.57	81.591
	3rd		89.481	81.798
	4th		145.29	133.09
	5th		191.81	162.95

Determination of material constants:

In this proposed work laminated composite specimens of eight layers are prepared to determine its mechanical properties. According to ASTM D2309/D2309M (2008) standard, tensile test on specimen was performed. The mechanical properties were found from the experiment which was given in Table 7.

Table 7: Material constants of laminated composite plate

Ply orientation	E_{11}(GPa)	E_{22}(GPa)	G_{12}(GPa)	υ_{12}	Density(kg/m^3)
(0/90)4	12.030	12.030	2.5	0.25	1530

E_{11}= elastic modulus in longitudinal direction E_{22}= elastic modulus in traverse direction G_{12}= shear modulus in plane 1-2

υ_{12} = Poisson‟s ratio in plane 1-2

EXPERIMENTAL AND NUMERICAL RESULTS

In this proposed work, three different layered laminated composite plates are prepared for modal analysis. The geometry properties of specimens are 235mmx235mm, 235mmx156.6mm, 235mmx117.5mm. The material properties are given in the table.7. The central cut-out with varying multiple holes laminated composite plate are considered which are shown in Fig.24. Also, this proposed work consider the effect of cut-out ratio (d/D ratio where „D‟ is the side of centrally located square cut-out and „d‟ is the side of multiple square cut-out located both side of central cut-out) ,no of layers, position of cut-out, aspect ratio(a/b ratio where a and b are length and width of composite plate respectively), different boundary condition and ply orientation on natural frequency of cut-out. The different cut-out ratio (d/D ratio) such as 0.1, 0.2, 0.3 and 0.4 of laminated composite plate are considered for the dynamics analysis of composite plate which are shown in Appendix. There is a comparison between natural frequency of central square cut-out of laminated composite plate and central square cut-out with multiple holes of laminated composite plate based on equal area of cutting.

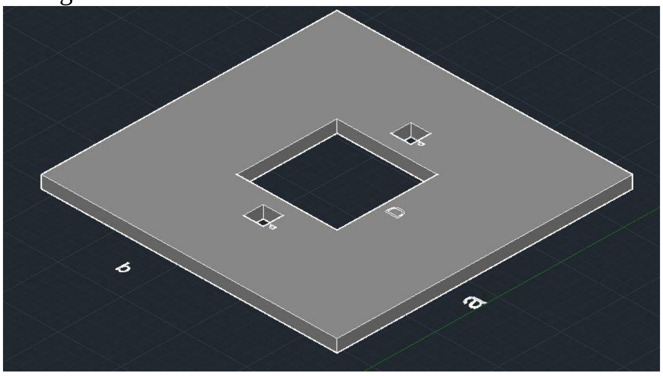
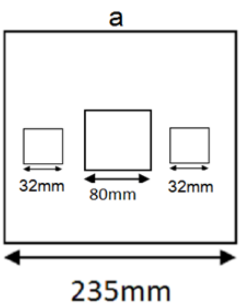


Fig.24: Composite plate with central square cut-out of side (D) with multiple square holes of side (d)

Effect of equal area of cutting

To study the variation of natural frequency between central cut-out with and without multiple holes based on equal area of cutting of the laminated composite plate are investigated. Two different samples having dimension 235mmx117.5mmx3mm are casted and material properties are given in table 7. The size of centrally located cut-out with multiple holes are 80mmx80mm at centre and 32mmx32mm at two side of the central cut-out (80x80+2x32x32=8448mm^2) which is also shown in Fig.25. The size of centrally located cut-out without multiple holes is 91.9mmx91.9mm (8448mm^2) which is shown in Fig.26. Two different end conditions such as CFFF and SFSF are considered. The end conditions are applied along the length of composite plate. The variation of natural frequencies between central cut-out with and without multiple holes based on equal area of cutting of the laminated composite plate under CFFF and SFSF boundary conditions are investigated in Fig:27 and Fig:28.



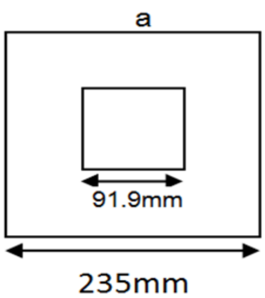


Fig.25:Central cut-out with multiple holes Fig.26:Central cut-out without multiple holes

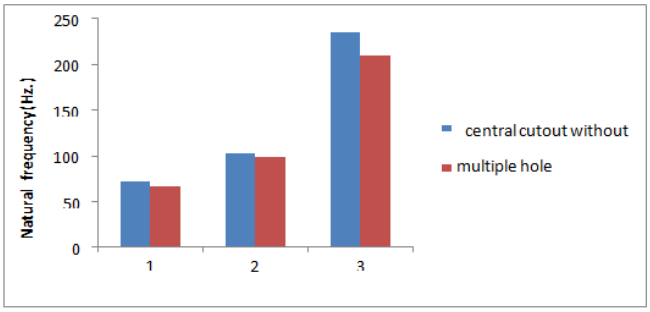


Fig.27: Variation of frequencies between central cut-out without holes and with multiple holes based on equal area of cutting under CFFF end condition

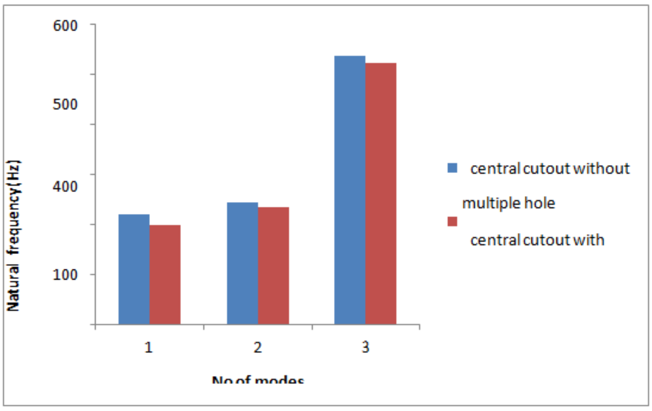


Fig.28: Variation of frequencies between central cut-out without holes and with multiple holes based on equal area of cutting under SFSF end condition

The investigation is related to the composite plate with SFSF (two opposite sides simple supported and others free) and CFFF (one side clamped and others free) restrained conditions, the results of which are presented in Fig: 27 and Fig: 28. The experimental natural frequencies of central cut-out with multiple holes are found to decrease by 10.21% from the experimental values of central cut-out without multiple holes for 1st mode and about 3.6% and 2.79% for 2nd and 3rd mode respectively for SFSF boundary condition and 8.4%, 4.5% and 10.81% for CFFF boundary condition respectively. This may be due to localisation of stress concentrations is reduced around central cut-out resulting declination in stiffness of laminated composite plate.

Effect of position of cut-out.

To study the influence of position of cut-out on dynamics characteristics of laminated composite plate, three different specimens are casted whose position of cut-out are at the centre, corner and side of the support. The geometry of specimens is 235mmx235mmx3mm, cut-out size of 80mmx80mm and material properties are given in the table 7. Both numerical and experimental results on natural frequency of composite plate for SFSF and CFCF boundary condition are presented. The natural frequencies for laminated composite plate having three different position of cut-out are presented in Fig: 29 and Fig: 30.

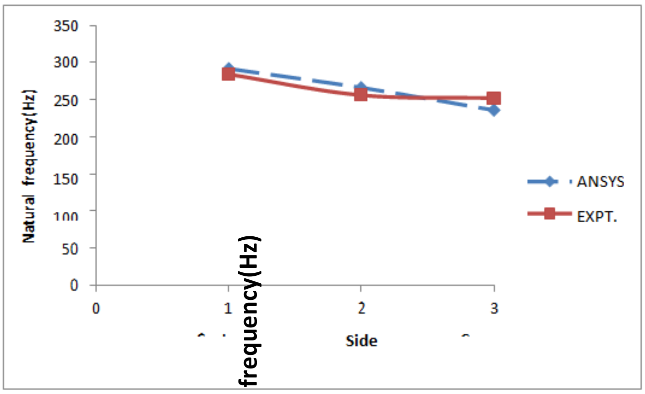


Fig.29: Variation of natural frequency laminated composite plate with different position for CFCF boundary condition

The relation between natural frequency and their relative position of the cut-out is plotted under CFCF and SFSF boundary condition. It is observed that in case of CFCF and SFSF end conditions maximum natural frequency occurs at centre position and minimum at corner position. From experimental values, it shows that natural frequency reduces about 9.85% from centre to side and about 11.20% from centre to corner position of cut-out in CFCF end condition. But in SFSF end condition natural frequency reduces about 1.78% from centre to side and about 17.8% from centre to corner position of cut-out respectively.

Effect of cut-out ratio (d/D ratio)

The influence of different cut-out ratio (d/D) on vibrational properties of composite plates are discussed for plate size of 235mmx117.5mmx3mm.(where D is the side of centrally located square cut-out and d is the side of multiple square cut-out located both side of central square cut-out).The central square cut-out of size 80mmx80mm and cut-out ratio (d/D) 0.0,0.1,0.2,0.3 and 0.4 are considered i.e. side of multiple square cut-out vary 0mm,8mm,16mm,24mm and 32mm. The end conditions are applied along the length of composite plate. The variation of natural frequency due to cut-out ratio under different boundary condition is examined in Fig: 31, Fig: 32 and Fig: 33.

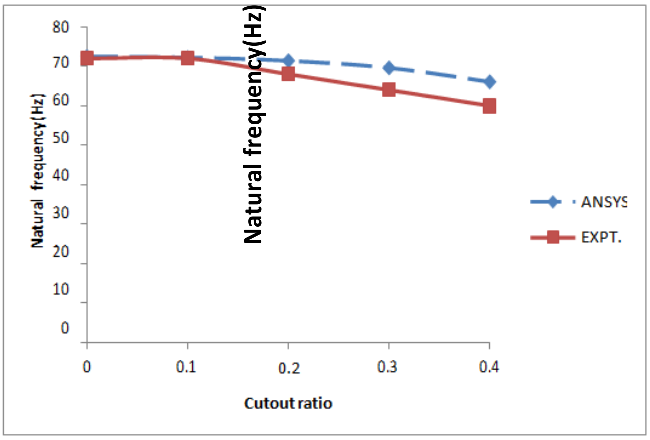


Fig.31: Variation of fundamental frequency for laminated composite plate with cut-out ratio (d/D ratio) under cantilever boundary condition

From this analysis, it is observed that at cut-out ratio=0.1, the frequency of specimen is least affected under CFFF boundary condition and also shows that the fundamental natural frequencies are considerable affects due to large cut-out ratio. It is also concluded from this investigation, the natural frequency decreases due to the increase in cut-out ratio. The experimental fundamental frequencies of cut-out ratio 0.1, 0.2, 0.3 and 0.4 are found to decrease by 0%, 5.55% ,11.11% and 16.6 % respectively as compared to fundamental frequency of cut-out ratio=0.0 under CFFF end condition

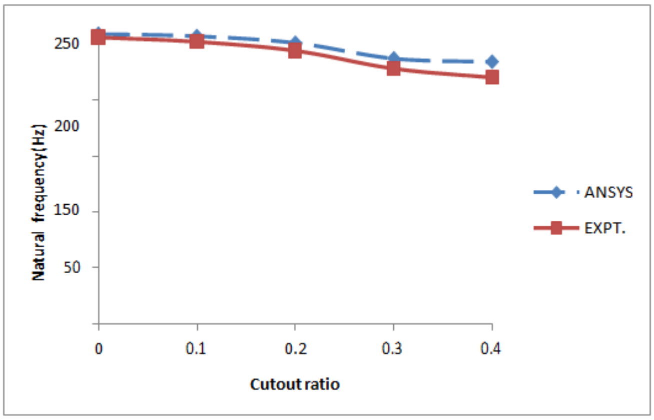


Fig.32: Variation of fundamental frequency for laminated composite plate with cut-out ratio (d/D ratio) under SFSF boundary condition

The same study has been extended to the composite plate under SFSF (two opposite sides are simple supported and others are free) condition, the results of which are plotted in Fig. 32. The experimental fundamental frequencies of cut-out ratio 0.1, 0.2, 0.3 and 0.4 are found to decrease by 1.56%, 4.68%,10.93% and 14.06 % respectively for SFSF boundary condition as compared to laminated plate with cut-out ratio=0.0.

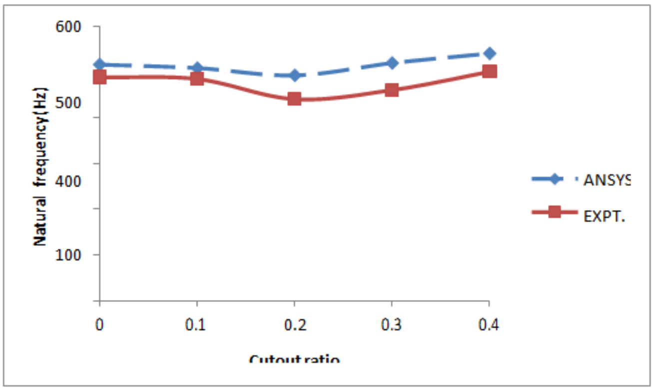


Fig.33: Variation of fundamental frequency for laminated composite plate with cut-out ratio (d/D ratio) under CFCF boundary condition

The mode shapes related with natural frequencies of (0/90)4s composite plate under CFCF end condition have been demonstrated in Fig. 34, Fig. 35, Fig.36, Fig.37 and Fig. 38 for cut- out ratio (d/D ratio) 0.0, 0.1, 0.2, 0.3 and 0.4 respectively. They are construed by using ANSYS package for fundamental frequencies of different cut-out ratio (d/D ratio) i.e. 0.0, 0.1, 0.2, 0.3 and 0.4 under CFCF restrained condition.

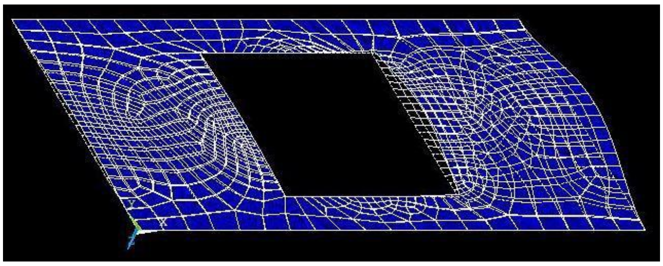


Fig.34: First mode shape (515.5 Hz) of laminated composite plate of size 235mmx117.5mmx3mm for cut-out ratio (d/D ratio) = 0.0

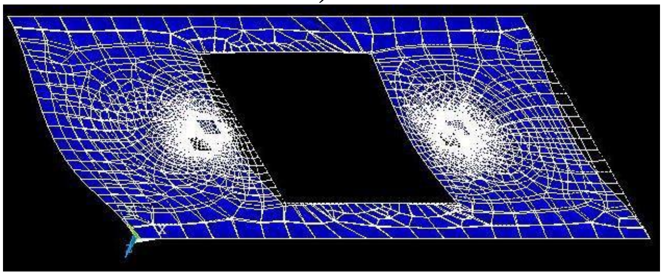


Fig.35: First mode shape (508.8Hz) of laminated composite plate of size 235mmx117.5mmx3mm for cut-out ratio (d/D ratio) = 0.1

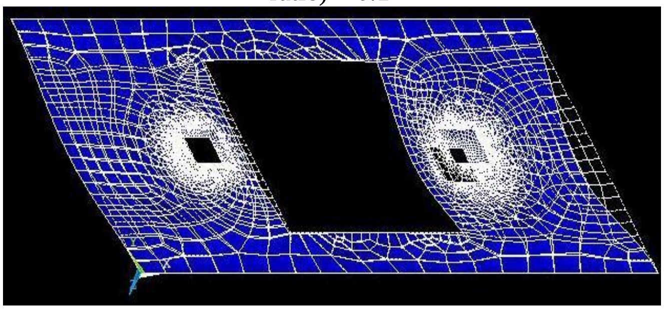


Fig.36: First mode shape (492.5 Hz.) of laminated composite plate of size 235mmx117.5mmx3mm for cut-out ratio (d/D ratio) = 0.2

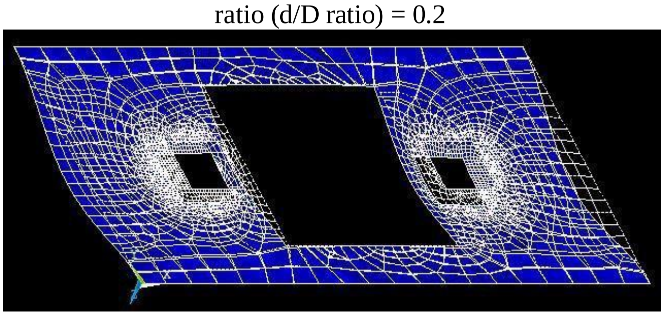


Fig.37: First mode shape (519 Hz)of laminated composite plate of size 235mmx117.5mmx3mm for cut-out ratio (d/D ratio) = 0.3

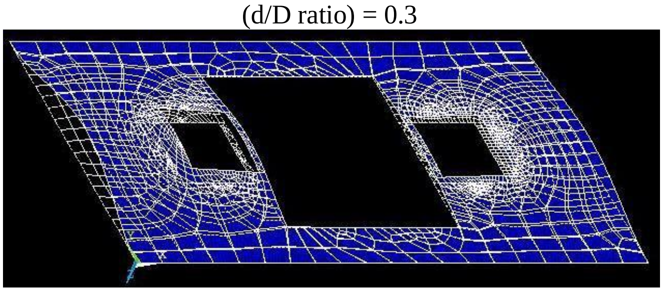


Fig.38: First mode shape (540 Hz) of laminated composite plate of size 235mmx117.5mmx3mm for cut-out ratio (d/D ratio) = 0.4

From the above graph, the fundamental frequencies of laminated composite plates decrease up to cut-out ratio (d/D ratio) equals to 0.2. Since the localisation of stress concentration is reduced by providing multiple square holes around the square central cut-out. Hence there is stiffness reduction of plate. Further natural frequency increases with increase in cut-out ratio (d/D ratio).

Effect of aspect ratio (a/b)

To examine the effect of aspect ratio on vibration behaviour of laminated composite plate of cut-out ratio (d/D ratio=0.4) are discussed. There are three different aspect ratio i.e. a/b=1,a/b=1.5 and a/b=2 are considered. The geometry properties of three different aspect ratio (a/b) are shown in table 8. The end conditions are applied along the length of composite plate. The dimensions of different aspect ratio are given in table. The variation of fundamental frequency of laminated plate with different aspect ratio (a/b ratio) for cut-out ratio=0.4 are demonstrated in Fig: 39 under CFCF boundary condition.

Table 8: The geometry properties of three different aspect ratio (a/b)

Aspect ratio(a/b)	Length(mm)	Width(mm)	Thickness(mm)
1	235	235	3
1.5	235	156.6	3
2	235	117.5	3

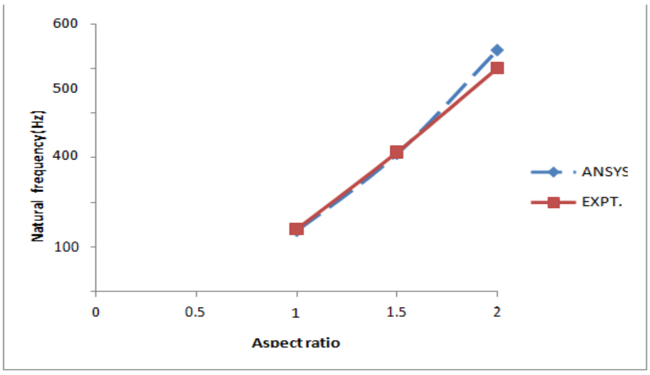


Fig.39: Variation of fundamental frequency of laminated plate with different aspect ratio (a/b ratio) for cut-out ratio=0.4 under CFCF end condition

It is found that the experimental fundamental natural frequency of composite plate with cut- out ratio=0.4 under CFCF boundary condition for aspect ratio 1.5 and 2.0 increases by 55.12% (from 140 Hz to 312 Hz) and 72% (140 Hz to 500 Hz) respectively as compared to aspect ratio 1.0. It also specifies that the fundamental frequencies of a laminated composite plate considerable increases with increase in aspect ratio (a/b).

Effect of no of layers of composite plate

Three different layers such as 4,8 and 12 layers are taken in this proposed work to investigate the influence of no of layers on fundamental frequencies of plate with cut-out ratio(d/D ratio=0.4). The geometry properties of plates are 235mmx235mmx1.5mm and 235mmx235mmx4.5mm for 4 and 12 layers respectively. The end conditions are applied along the length of composite plate. The densities of the specimens are calculated 1545 kg/m^3 and 1476 kg/m^3 for 4 and 12 layers respectively. The fundamental frequencies of laminated plate of cut-out ratio=0.4 w.r.t no of layers is presented in Fig: 40

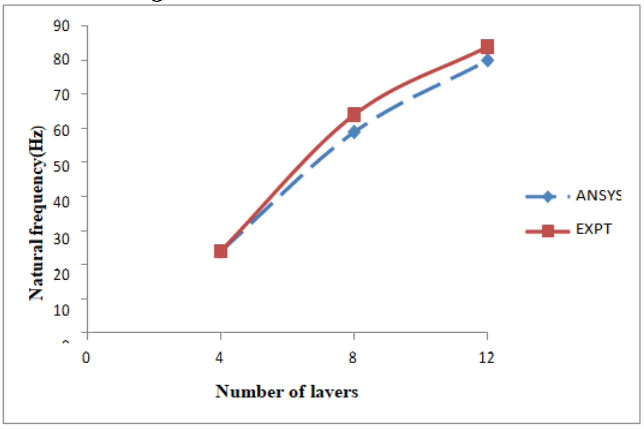


Fig.40: Variation of fundamental frequency of laminated plate of size 235mmx235mm with number of layers for cut-out ratio=0.4

From this above graph, it indicates that the fundamental frequencies of plate increases with increase in number of layer in composite plate. Also, it is observed that the fundamental frequencies of composite plate of cut-out ratio =0.4 for 8 layers and 12 layers is increased by 2.6 times and 3.5 times respectively w.r.t 4 layered laminated plate. This result shows that more no of layers has a positive effect on the stiffness of laminated composite plates.

Effect of ply orientation

Three different ply orientation such as $(0/90)_4$, $(45/-45)_4$ and $(30/-60)_4$ are considered in the present study to examine the effects of ply orientations on natural frequencies of laminated composite plate with cut-out ratio (d/D ratio=0.4). The geometry property of plate is 235mmx235mmx3mm.The young‟s modulus of elasticity of composite plate corresponding to ply orientations $(30/-60)_4$ and $(45/-45)_4$ are 8.788 GPa and 7.574 GPa respectively. The end conditions are applied along the length of composite plate. The variation of fundamental frequency of laminated plate with respect to fibre orientation for cut-out ratio=0.4 is shown in Fig: 41

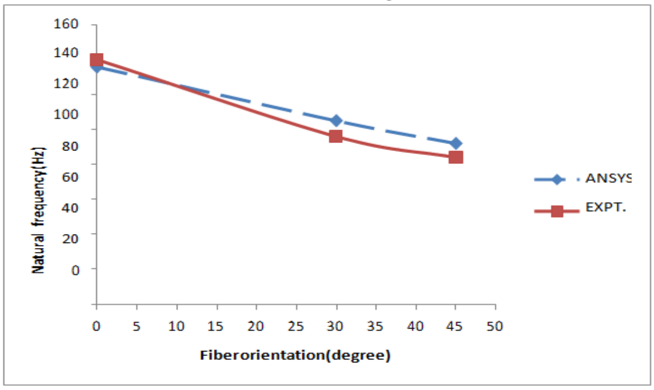


Fig.41: Variation of fundamental frequency of laminated plate with respect to fibre orientation for cut-out ratio=0.4

From this above graph, it finds that the experimental results show a good agreement with ANSYS results verifying that the ply orientation of fibre has been the effect on vibrational analysis of the laminated composite plates. The natural frequencies of plate decrease with increasing fibre angle. It is observed that increasing the orientation from 0^0 to 45^0 decreases the natural frequency by about 40% (from 140 Hz to 84Hz) for 1st mode. It is possible to verify the effect of fibre orientations on the free vibration of laminated plate. It is found that maximum natural frequency occurs at 0^0 and minimum at 45^0.

Effect of boundary condition

To investigate the effect of boundary condition on vibrational properties of eight layers laminated composite plate of size 235mmx235mmx3mm with cut-out ratio(d/D=0.4). The boundary conditions considered for present investigation are CFFF, SFSF and CFCF. The natural frequencies of glass epoxy composite plate with cut-out ratio (d/D=0.4) under three different boundary conditions are drawn in Fig.42.

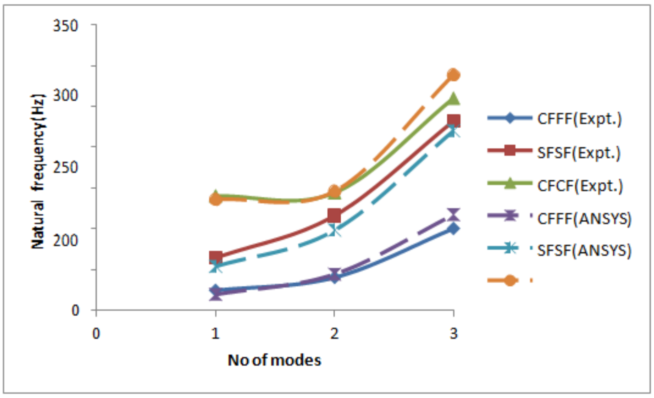


Fig.42: Variation of natural frequency of laminated plate of size 235mmx235mmx3mm with different boundary conditions for cut-out ratio=0.4

From this graph, It shows that the first, second and third mode of frequencies are least for CFFF (one side is clamped and other three sides are free) end condition and the maximum for CFCF boundary condition. The fundamental frequency for cut-out ratio=0.4 at CFFF and SFSF boundary conditions are decreased by 85.97% and 60.58% respectively with respect to CFCF boundary condition. This result indicates that the boundary conditions have large influence on the natural frequencies of laminated composite plate.

There is deviation of results between numerical values and the experimental values due to some possible error during measurement such as position of accelerometer, noise, mass of specimen, non-uniformity in properties of specimens (non-uniform surface finishing, voids and different thickness). These factors are not considered during numerical analysis, meanwhile the model of specimens are considered as homogeneous properties and fully perfect which is not possible in real life. Also, they do not considered irregular distribution of resin on the fibres. Models also do not consider damping effect which is large application effect on modal analysis of structure. Also, the finite element package ANSYS does not permit fibre interweaving present in composite plate.

Pulse report

The natural frequency of the laminated composite plate is recorded during free vibration test by inserting pulse software to computer. The pulse reports for laminated composite plate are

shown in Fig: 43 and Fig: 44. The peaks of the FRF shown in Fig: 43 give the natural frequencies of free vibration. The coherence shows the accuracy of measurement during vibration test which is shown in fig: 44.

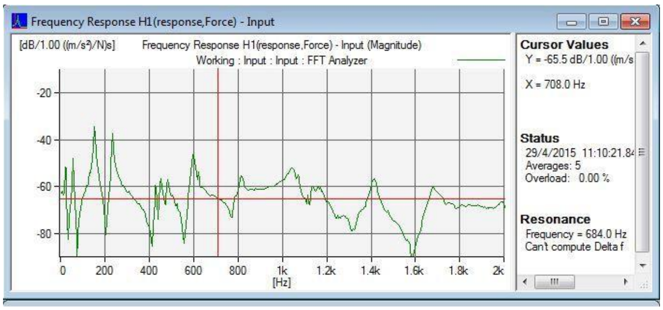


Fig 43: Frequency response function spectrum (X-axis indicates Frequency(Hz) and Y- axis indicates acceleration per force ((m/s2)/N))

Fig 44: Coherence (Response, Forc

The present study is related with the effect of the free vibration behaviours on laminated composite plates with cut-outs. The finite element package ANSYS is used to investigate the laminated composite plate with cut-outs. The experimental results of free vibration behaviours of laminated composite plate with cut-outs are compared with numerical ones by considering the effect of various parameters such as cut-out ratio (d/D ratio), aspect ratio (a/b ratio), fibre orientation, no of layers , position of cut-out and different boundary conditions etc. From this analysis, we can be established the following remarks during the investigation of free vibration behaviours of laminated composite plate with cut-outs.

- The numerical results from ANSYS software showed in good agreement with experimental ones on vibration of laminated plates.
- The natural frequencies of plates increases with increase in aspect ratio (a/b) of plates by keeping the cut-out ratio (d/D ratio) constant.
- By keeping aspect ratio (a/b ratio) constant, as the cut-out ratio (d/D ratio) increases from 0.0 to 0.4 the fundamental frequency of composite plate decreases under CFFF and SFSF boundary conditions. But fundamental frequency decreases up to cut-out ratio (d/D ratio) equals to 0.2 under CFCF. Further fundamental frequency increases on increase of cut-out ratio d/D ratio. Since localisation of stress concentration is reduced by providing the multiple holes around the central cut-out
- Natural frequency of composite plate with square cut-out is maximum at centre and minimum at corner position irrespective of CFFF and SFSF boundary conditions.
- It is observed that natural frequency of composite plate with central cut-out without multiple holes is more than the natural frequency of plate with multiple holes.
- The fundamental frequencies of composite plate with fixed cut-out ratio, increase with increase in no of layers due to bending stretching coupling.
- By changing the ply orientation of laminates, it changes the dynamics characteristics of the plates, that is different frequencies for same geometry, mass and end
- conditions. As the ply orientation increases, the natural frequency decreases and maximum natural frequency occurs at 0^0.
- The natural frequency of laminated plate with holes varies against different end conditions. It shows that the natural frequency under CFCF boundary condition is the maximum due to clamped at two opposite edges. However, the CFFF supported laminated composite plates shows the minimum frequency among three boundary conditions tested.

From the above conclusion, the vibration characteristics of laminated plates with cut-out is affected by the different geometry properties, boundary conditions, ply orientation, cut-out ratio and position of cut-outs. The presence of cut-out may be weakening the structure under the dynamic loading and causes resonance due to reduction in natural frequency. So cut-outs play a vital role on the vibration characteristics of the plate structures. So the designers have to be cautious while designing the structures with cut-outs. The vibration results of the laminated composite plates can be used as a tool for structural health monitoring and also helps in assessment of structural integrity of composite structures.

FUTURE SCOPE OF RESEARCH

In the proposed work, the natural frequency of laminated composite plate is computed both numerically and experimentally. The influences of various parameters such as cut-out ratio, fibre angle, aspect ratio, no of layers and different position of cut-out are analysed under different boundary conditions. The future scope of the present work can be expressed as follows.

- The present investigation is related to the square size cut-out. This can be extended for different shape of cut-out.

- Force vibration analysis of laminated composite plate with cut-outs can be extended.
- Dynamics analysis of stiffened plates with cut-out may be extended for future study.
- The present research work can be extended to free vibration analysis of shells with cut-out.
- The present investigation can be extended to vibration analysis of composite plates with delamination around cut-out.
- The present study deals plates with uniform thickness. The plate can be modified to non-uniformity in thickness.
- Free vibration of composite plate with cut-out can be extended in hygrothermal environment.
- Buckling analysis and dynamic stability of laminated composite plate with cut-out can be studied.

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