

Effect of Hole Size on Free Vibration Analysis of Glass Fiber Composite Laminated Plate

Pranija Bartere ¹

Assistant Professor, Department of Mechanical Engineering, Indira college of Engineering & Management, Pune, India¹

ABSTRACT: This research present a combined experimental and numerical study of free vibration of glass fiber epoxy composite plates. Composite laminates were manufactured by compressive molding technique of unidirectional glass fiber with stacking sequence [0/90] orientation also coupons is manufactured as per ASME standards .Plate with a cutout shows a dynamic. First develop an experimental set up FFT analyser for finding response of plates. After that the composite laminated plates was modeled in ANSYS finite element package and solved using ANSYS parametric design language (APDL) code. Number of different boundary conditions are involved cantilever and fixed boundary condition .Experimentally by FFT analyser natural frequency and mode shapes is calculated for all plates with and without. Comparison is done by both the results and calculating errors in term of percentage.

KEYWORDS: ANSYS, composite laminates, free vibration, glass fiber, cutouts size.

I. INTRODUCTION

A variety of fibers are available as reinforcement for composites. The characteristics of most fibers are high strength, high stiffness, and relatively low density. A reinforced composite material that consists of fiber and matrix that are combined at a macroscopic level. There are two phases of composite exists namely, reinforcing phase and matrix phase. The reinforcing phase material may be in the form of fibers, particles which is responsible for carry loads and the and the matrix phase materials are generally polymer, metal, carbon and glass which is to distribute the force and stresses uniformly .It prevents fiber from external damage.

IMPORTANCE OF PRESENT STUDY

Fiber reinforced composites are increasing applications in various fields. In some of these applications the composites are subjected to loads. The composite structures may sometimes provide with different types of cutouts for the purpose of assembling the components, for passing the cables and control mechanisms, for inspection, maintenance and attachment to other units. The excellent stiffness to weight ratio, specific strength and other required properties of Fiber reinforced laminates make them first choice of designers in structural applications.

IMPORTANCE OF CUTOUTS IN STRUCTURE

Cutouts in a structure is an integral part of almost every structural element including laminated composite plates. They are used in civil, mechanical, aerospace and automotive industry. For various practical reasons always need to provide cutouts in these structures. Cutouts used in the mechanical and electrical systems such as passage of electrical wires, hydraulic lines etc. Many times designers just use cutouts of various shapes and size for quality control, to reduce the weight the weight of structures and also to alter the natural frequencies of structures to make them safe in case of hazardous vibrations. Cutouts in structural members like plates tend to change its dynamic characteristics to some extent. This change is obvious whenever the structure is exposed to large vibrations. Many a times these cutouts may lead to failure under lower stress and also sometimes due to undesired resonance. So it is utmost necessary to predict the resonant frequencies of these structures with cutouts.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 11, November 2016

PROBLEM STATEMENT

In order to achieve the right combination of material properties and service performance, the dynamic behaviour is the main point to be considered. To avoid the typical problems caused by vibrations, it is important to determine

- a) Natural frequency of the structure.
- b) The modal shapes to reinforce the most flexible regions or to locate the right positions where weight should be reduced or damping should be increase.

OBJECTIVES OF RESEARCH

1. To find out tensile strength, compressive strength and flexural strength of laminated composite.
2. Develop an experimental set up to find the natural frequency and mode shapes of laminated composite plates.
3. Validated experimental results with finite element software.

METHODOLOGY OF RESEARCH WORK

Manufacturing of composite laminated plate by compressive molding method made of E-glass fiber epoxy. Cutting of plated with a water jet machining technique of required dimensions. Develop an experimental set up with FFT analyzer, which is used to find mode shapes and natural frequency of plates. Two boundary condition is used cantilever and fixed condition. Modal analysis is perform in ANSYS and find natural frequency and mode shapes. Comparing the FEA values and experimental values.

II. SELECTION OF FIBER FOR LAMINATED PLATES PROCEDURES

Resins Selection for Composite

Epoxy resins are regarded as compounds which contain more than one epoxy group, capable of being converted to cured (thermoset) form with the help of hardener curing agents.



Fig 1: Resin Selection For Composites (a) LY 554 IN Epoxy and HY 951 Hardener (b) E-Glass Fiber Rolling Sheet

Manufacturing Of Composite Laminated Plates Process

In initial a flat mold was selected of dimension 150×600mm. Ply was cut from roll of unidirectional glass fiber of dimension 147×470mm in [0°-90°] orientations.

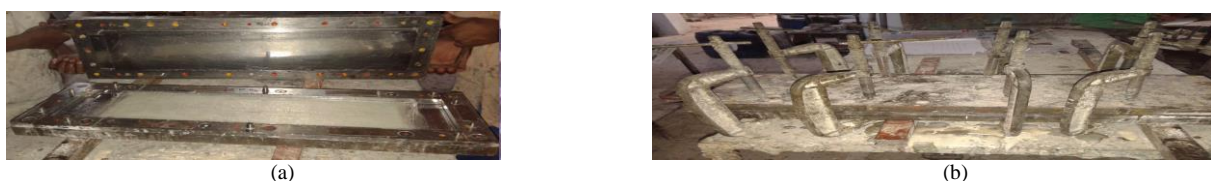


Fig. 2 (a) & (b) die for Compressive moulding

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 11, November 2016



Fig. 3: (a) & (b) Manufacturing of Laminated composite plate with or without cutouts

III. TESTING OF LAMINATED COMPOSITE PLATES BY ASTM STANDARD

Tensile Test

Table 1 : Tensile Strength (ASTM D 638-03)

Sample Identification	Material	Maximum Load(N)	Tensile Strength (Mpa)
1. Sample	E-Glass Fiber 0/90°	25529.0	357.34
2. Sample	E-Glass Fiber 0/90°	17787.0	343.17

$$\text{Tensile Strength} = \frac{\text{Load at break}}{\text{Original width} \times \text{Original thickness}} = \frac{25529.0}{18.95 \times 3.77} = 357.341 \text{ MPa}$$

Compressive Test

Table 2 : Compressive Strength (ASTM D 695-02)

Sample Identification	Material	Maximum Load(N)	Compressive Strength (Mpa)
1. Sample	E-Glass Fiber 0/90°	46256.0	309.25
2. Sample	E-Glass Fiber 0/90°	41914.6	280.46

$$\text{Compressive Strength} = \frac{\text{Peak Load}}{\text{Cross sectional area}} = \frac{46256}{12.21 \times 12.25} = 309.25 \text{ MPa}$$

Flexural Test

Table 3 : Flexural Strength (ASTM D 790-03)

Sample Identification	Material	Maximum Load(N)	Flexural Strength (Mpa)
1. Sample	E-Glass Fiber 0/90°	912.38	148.43
2. Sample	E-Glass Fiber 0/90°	833.0	355.04

$$\text{Flexural Strength} = \frac{3PL}{2bd^2} = \frac{3 \times 912.38 \times 50}{2 \times 12.480 \times 3.620^2} = 418.4133 \text{ MPa}$$

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 11, November 2016

IV. EXPERIMENTAL FFT ANALYZER SETUP

Experimental setup includes experimental setup of FFT analyzer for cantilever and fixed condition of plate:



Fig. 4: Experimental setup of FFT Analyser

V. NUMERIAL FINITE ELEMENT ANALYSIS

Properties of E-Glass Fiber Composite Plate

Table4: Properties of E-Glass Fiber Composite Plate

Sr. No.	E_1 Gpa	E_2 Gpa	E_3 Gpa	G_{12} Gpa	G_{23} Gpa	G_{31} Gpa	V_{12}	V_{13}
1.	36.28	5.361	5.361	2.167	1.95	1.95	0.21	0.21

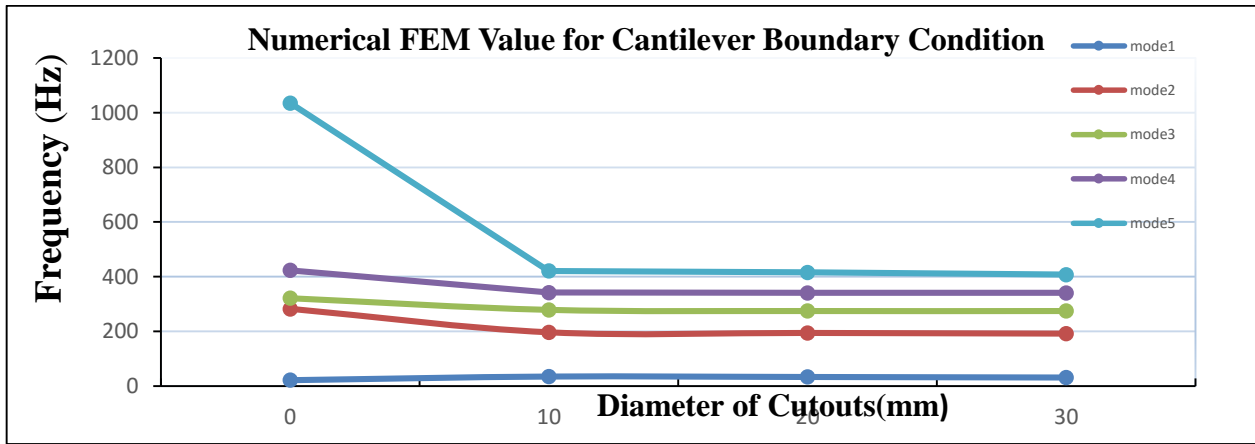
International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

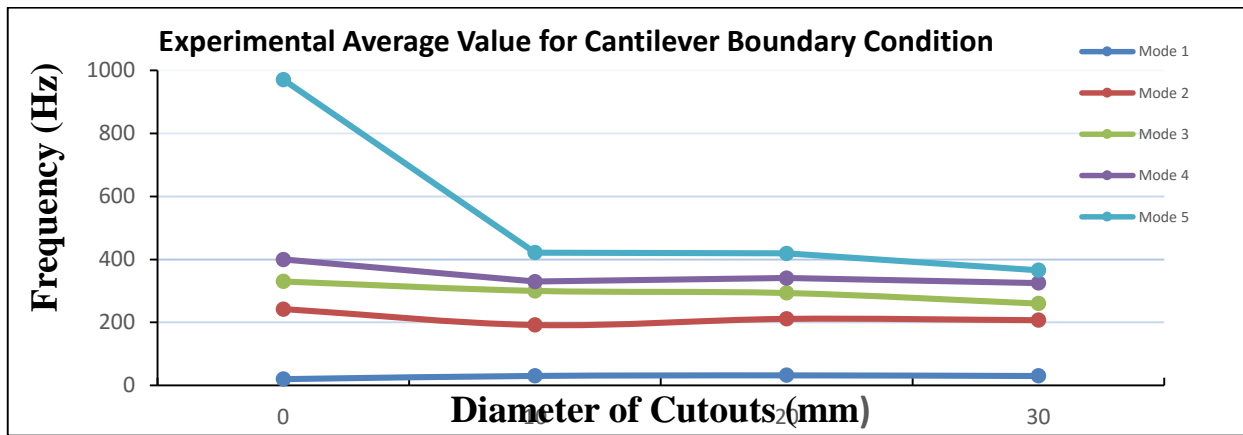
Vol. 5, Issue 11, November 2016

VI. RESULT AND DISCUSSION

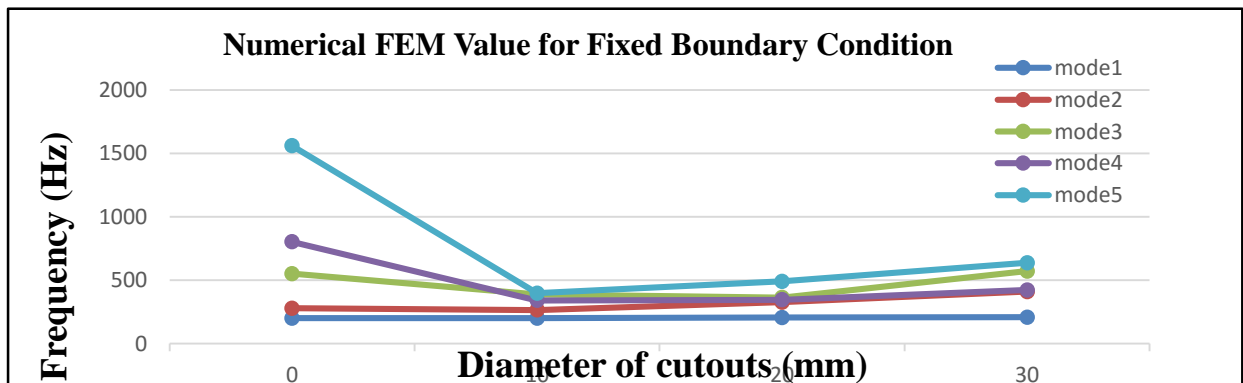
Comparison of Numerical FEM and Experimental Values of Cantilever or Fixed boundary Conditions



Graph1: Numerical FEM Value Graph for Cantilever Boundary Condition



Graph 2: Experimental Average Value Graph for Cantilever Boundary Condition

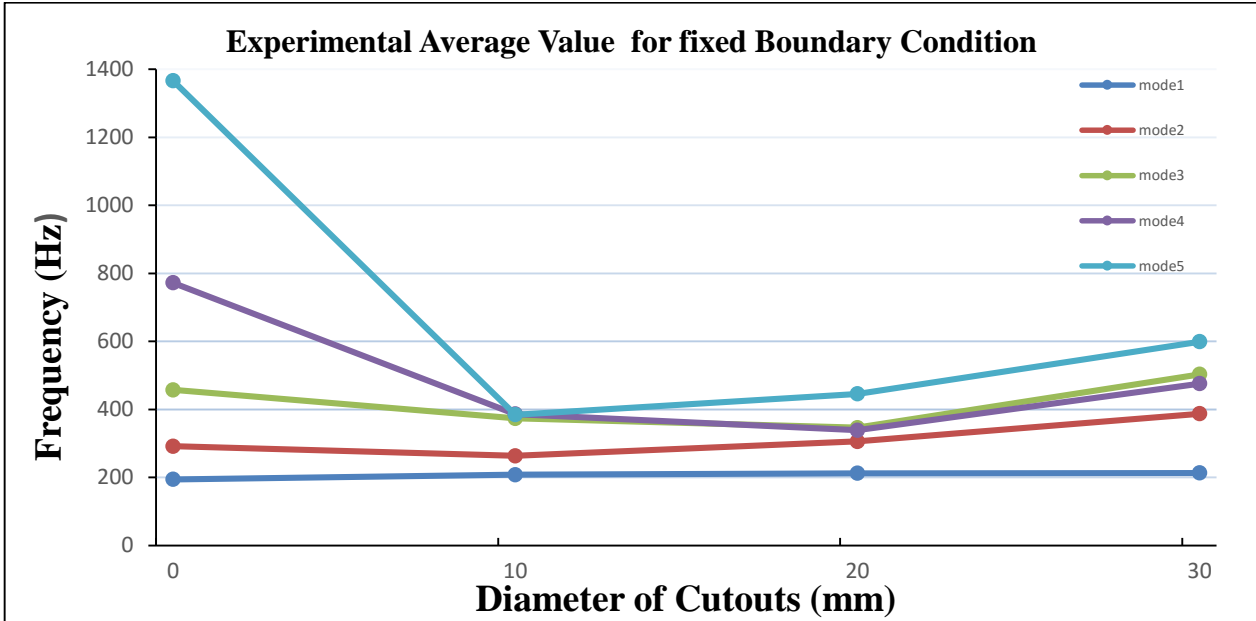


Graph 3: Numerical FEM Value Graph for Fixed Boundary Condition

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 11, November 2016



Graph 4: Experimental Average Value Graph for Fixed Boundary Condition

VII. COMPARISON OF MODAL TESTING OF COMPOSITE LAMINATED PLATES WITH AND WITHOUT CUTOUTS FOR EXPERIMENTAL AVERAGE AND NUMERICAL FEM VALUES

Table 5: Comparison of Modal Testing Of Composite Laminates without Cutout for Cantilever and Fixed Boundary Condition

Plate without cutout for cantilever boundary condition					Plate without cutout for Fixed boundary condition		
SR. No.	Modes	FEM	Experimental Average	% Error	FEM	Experimental Average	% Error
1	Mode 1	21.195	20.5	3.27	201.38	194.69	3.32
2	Mode 2	282.15	242.2	14.15	279.41	291.96	4.29
3	Mode 3	321.25	330.19	2.70	551.92	457.58	17.0
4	Mode 4	423.09	399.70	5.49	802.84	772.54	3.77
5	Mode 5	1035.3	971.10	6.20	1560	1366.3	12.4

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 11, November 2016

Table 6: Comparison of Modal Testing Of Composite Laminates with 10mm Cutout for Cantilever and Fixed Boundary Condition

Plate with 10mm cutout for cantilever boundary condition					Plate with 10mm cutout for Fixed boundary condition		
SR. NO.	Modes	FEM	Experimental Average	% Error	FEM	Experimental Average	% Error
1	Mode 1	34.854	30.69	11.94	201.56	208.22	3.19
2	Mode 2	196.26	192.01	2.16	264.96	263.77	0.44
3	Mode 3	278.73	300.53	7.25	387.36	373.98	3.45
4	Mode 4	341.63	329.86	3.44	341.58	386.42	11.60
5	Mode 5	420.73	421.86	0.26	398.02	384.41	3.41

Table 7: Comparison of Modal Testing of Composite Laminates with 20mm Cutout for Cantilever and Fixed Boundary Condition

Plate with 20mm cutout for cantilever boundary condition					Plate with 20mm for fixed boundary condition		
SR. No.	Modes	FEM	Experimental Average	% Error	FEM	Experimental Average	% Error
1	Mode 1	33.212	32.44	2.32	206.20	212.29	2.86
2	Mode 2	193.98	211.27	8.183	327.85	305.83	6.71
3	Mode 3	274.48	293.78	6.569	363.26	346.51	4.61
4	Mode 4	340.54	340.98	0.129	346.32	339.00	2.11
5	Mode 5	415.65	419.16	0.837	491.05	445.68	5.97

Table 8: Comparison of Modal Testing Of Composite Laminates with 30mm Cutout for Cantilever and Fixed Boundary Condition

Plate with 30mm cutout for cantilever boundary condition					Plate with 30mm cutout for fixed boundary condition		
Sr.No.	Modes	FEM	Experimental Average	% Error	FEM	Experimental Average	% Error
1	Mode 1	31.190	30.41	2.50	208.50	213.5	2.34
2	Mode 2	191.51	207.09	7.52	410.24	387.35	5.57
3	Mode 3	274.48	260.4	5.12	572.60	503.15	12.12
4	Mode 4	340.54	325.21	4.50	422.63	475.67	11.15
5	Mode 5	407.53	365.76	10.2	638.00	599.15	6.08

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 11, November 2016

VIII. CONCLUSION

Composite laminates were manufactured by compressive moulding technique of unidirectional glass fiber with stacking sequence $[0/90^\circ]$ orientation also sample coupons were manufactured as per ASME standards, to find out flexural strength, compressive strength, and tensile strength of E-glass fiber composite laminated.

Testing results of sample coupons

Coupons are tested as per ASTM standard gives a strength of composite laminated plate. **Tensile testing** of composite laminates obtained by **ASTM D 638-03** is **366.82 MPa**. **Compressive testing** of composite laminates by **ASTM D 695-02** is **297.10 MPa**. Also flexural test is conducted i.e. three point bend test of composite laminates by **ASTM D 790-03** is **311.27MPa**.

Effect of change in size of cutouts

In all the cases involving the various boundary conditions it is found that there is significant change in frequency in case of cut outs on the plate. In cantilever boundary condition as we increase a size of cutouts the frequency range is decreased but in case of fixed boundary condition as we increase a size of cutouts of plates a frequencies range is increased. The frequencies range which is obtained for plate without cutouts for cantilever and fixed condition is very high as we take a small cutouts of 10mm the frequency range is with in safe limit of 0 – 500 Hz.

REFERENCES

- [1] C.V. Srinivasa, Y.J. Suresh, W.P. Prema Kumar, "Experimental and Finite Element Studies on Free Vibration of Skew Plates", international Journal of Applied Mechanics and Engineering, Volume 19, No.2, pp.365-377.
- [2] Ronald F. Gibson, "Modal Vibration Response Measurements for Characterization of Composite Materials and Structures", Elsevier, Composite Science and Technology, 60(2000), pp.2769-2780.
- [3] Kanak Kalita And Abir Dutta, "Free Vibration Analysis Of Isotropic And Composite Rectangular Plates", International Journal Of Mechanical Engineering And Research, Issn No. 2249-0019, Volume 3, Number 4 (2013), pp. 301-308.
- [4] S. B. Singh, Himanshu Chawla, "Dynamic Characteristics of Glass Fiber Reinforce Polymer Laminates with Cutouts", International Journal of Applied Engineering Research, ISSN 0973-4562, Vol.7 No.11, 2012.
- [5] A. Naghsh, M. Azhari, "Non-Linear Free Vibration Analysis of Point Supported Laminated Composite Skew Plates", International Journal of Non-Linear Mechanics 76(2015), Elsevier, pp. 64-76.
- [6] Hakim S. Sultan Aljibori , W.P. Chong , T.M.I. Mahlia , W.T. Chong , Prasetyo Edi , Haidar Al-Qrimli ,Irfan Anjum , R. Zahari, "Load Displacement Behavior Of Glass Fiber /Epoxy Composite Plates With Circular Cut-Outs Subjected To Compressive Load", Elsevier Science Direct ,Materials And Design, 31 (2010) ,pp.466–474.
- [7] A. Houmat, "Nonlinear Free Vibration of Laminated Composite Rectangular Plates with Curvilinear Fibers", Elsevier, Composite Structure 1-06 (2013), pp.211-224.
- [8] M. Ganapathi, Amit Kalyani, Bhaskar Mondal, T. Prakash, "Free Vibration Analysis of Simply Supported Composite Laminated Panels", Elsevier, Composite Structures 90(2009), pp.100-103.
- [9] S. Hatami, M. Azhari, M.M. Saadatpour, "Free Vibration of Moving Laminated Composite Plates", Elsevier Science Direct, Composite Structure80 (2007), pp.609-620.
- [10] Daniel M.J. Peeters, Simon Heese, Mostafa M. Abdalla, "Stacking Sequence Optimization Stiffness Laminates with Manufacturing Constraints", Elsevier Science Direct, Composite Structure 125(2015), pp.596-604.
- [11] Rizal Zahari, Sulaiman Kamarulazizi and Dayang Laila Abang Abdul Majid, "Tensile Behaviour Of Unbalanced Woven C-Glass/Epoxy Composite Laminated Plate With And Without Circular Cutouts", Journal Mekanikal ,34(2012), pp.57-65.
- [12] Mohammad Vaziri, Ali Vaziri, Prof. S.S. Kadam, "Vibration Analysis Of Cantiliver Beam By Using Fft Analyser, International Journal Of Advanced Engineering Technology, Issn 0976-3945.
- [13] J. P. Talbot and J. Woodhouse, "The Vibration Damping of Laminated Plates", Elsevier, Science Direct, Composites Part a 28(1997), pp. 1007-1012.
- [14] Sharayu U. Ratnaparkhi, S.S. Sarnobat, "Vibration Analysis of Composite Plate", International Journal of Modern Engineering Research (Ijmer) Vol.3, Issue.1, ISSN: 2249-6645, pp-377-380.