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MODAL ANALYSIS OF E-GLASS WOVEN ROVING COMPOSITE PLATE

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ABSTRACT :

Now days, the composite materials are widely used. The composite materials have potential to replace the metals, if they prepared by considering the effects of compositions and number of layers on its mechanical properties. This paper mainly focused on the fabrication techniques of composites and their testing techniques. First the mechanical properties are tested on UTM. The life of composite material affected by vibration, so the natural frequency was calculated by analytical way and experimental natural frequency observed by FFT. The mechanical strength also observed in ANSYS software. The errors between theoretical and experimental values are compared and predictions are made on cause of errors. Through the comprehensive study and testing this paper attempted to bring experimental and analytical methods in light for composite material testing.

INTRODUCTION :

The composite materials are differing from commonly used heterogeneous materials. The composite materials are material having stronger fibers which are surrounded by weaker material matrix. [1] The composites are of different kind the popular types are polymer matrix composites (PMCs), metal matrix composites (MMCs), and ceramic matrix composites (CMCs), as well as particle-reinforced composites. [2] The composite material shows high strength-to-weight ratios, corrosion resistance, tailored properties, and design flexibility, making them suitable for a wide range of applications in industries like aerospace, automotive, marine, construction, and electronics.

The fiber-reinforced composites (FRCs) are produced by combining a polymer matrix with fibrous materials, which shows key properties like High Strength-to-Weight Ratio, increased stiffness, corrosion restiveness.

Very often the composite materials are subjected to dynamic loading. The dynamic loading produces repeated vibrations which finally lead to fatigue, causing micro cracks and delamination over time. Very little work is done in the field of FRP composite materials testing. This paper attempt to discuss testing experiments carried out to test E-glass woven roving composite material and explore the parameters which are dependent on vibration.

METHODOLOGY :

In the first stage the E-glass woven roving composite plate is crafted The developed composite plate is tested with FFT for vibration analysis and natural frequency is determined for resonance. With the help of ANSYS software, finite element analysis is conducted and frequency response results are obtained. Also a comparison is made between analytical, simulation and experimental results for understanding of factor affecting the percentage error.

FABRICATION METHOD :

Now a day, the verity of composite manufacturing techniques are available. The hand lay-up and spray-up manufacturing techniques is widely used. For preparing test sample we used 1:1 weight ratio of fiber to matrix. Plies of WR are joined in the required order using contact moulding in an open mould by hand lay-up. The spray gun was used to apply a thin layer of polyvinyl alcohol as a releasing agent. In order to provide a smooth outside surface and shield the fibers from direct environmental exposure, laminating begins with the application of a gel coat (epoxy and hardener) that is brushed onto the mould. From a roll of woven roving, ply was cut. After applying layers of reinforcement to the mould over the gel coat, the gel coat was brushed on once again. Steel rollers with serrated edges were used to release any trapped air.

SPECIMEN SPECIFICATIONS

Laminate with eight layers is produced for material characterization of composites in order to assess the material constants. Tensile tests have conducted on specimens in accordance with ASTM standards D 638-08 and D 3039/D 3039M-2006 in order to experimentally determine the constants. In every instance, a thin, flat strip of the specimen with a constant rectangular cross section is needed to created. The dimension of specimen is as mentioned in table 1.

Table 1 Size of the specimen for tensile test

Length (mm)	Width (mm)	Thickness (mm)
165	13	4

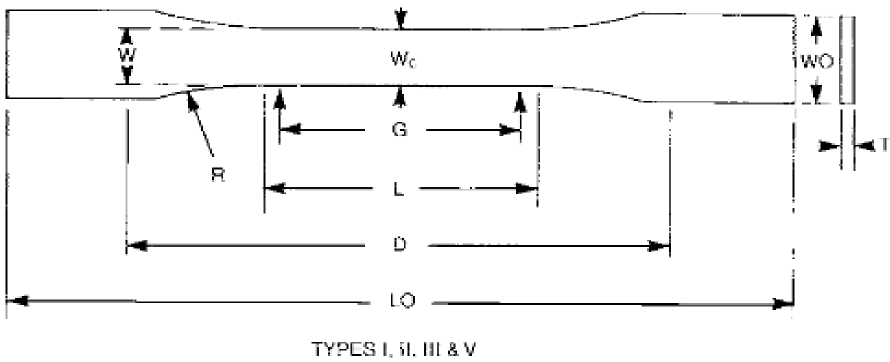


Figure 1 Dimensions

Dimensions	**7 mm or under** **4 or under Type I**	**Tolerances**
W-Width of narrow section	13	± 0.5
L- Length of narrow section	57	± 0.5
Wo- Width overall min.	19	+6.4
Lo-Length overall min.	165	No max.
G- Gauge length	50	± 0.25
D- Distance between grips	115	±5.0
R-Radius of fillet	76	± 1.0

Table 2 Dimensions as per D 638-08 ASTM Standard

Experimentation

The spacemen are rigorously tested for mechanical properties on Universal Testing Machine, the vibrations analysis is done and the computer added analysis used to verify results

Experimentation for mechanical properties UTM

The specimen is tested on UTM to measure the Young's modulus. The rate of loading is kept 5mm/minute. A load cell and an extensometer are used to digitally record the load and the extension, respectively. A plot of the stress vs. strain curve created using these data; the Young's modulus is indicated by the curve's slope. The value of Young's modulus found 2.34e10. Using two strain gauges in the longitudinal and transverse directions, the Poisson's ratio can be obtained directly from the ratio of transverse to longitudinal strain. 0.171 is the calculated value of Poisson's ratio.

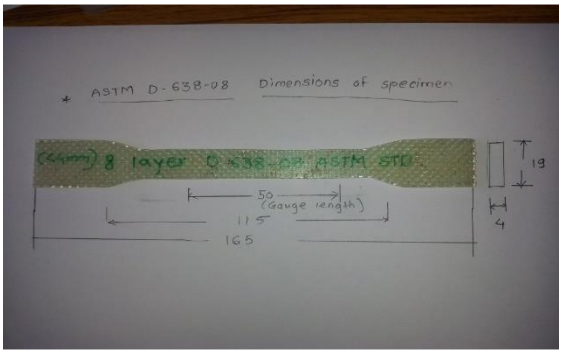


Fig 2 ASTM D 638-08 Specimen

Figure3. Tensile test of woven fiber Glass/Epoxy composite specimen on UTM

Finding natural frequency

Using Euler's Bernoulli Theory find out Natural frequency of plate at free- free boundary condition,

Natural Frequency $=(\beta_n l)^2 X \sqrt{\frac{E\times I}{\rho\, A l^4}}$ rad/sec

Natural Frequency $=\frac{1}{2\pi}(\beta_n l)^2 X \sqrt{\frac{E\times I}{\rho\, A l^4}}$ Hz

Where,

E −Modulus of Elasticity N/m2

I − Moment of Inertia m4

l − Length, m

ρ − Material density Kg/m3

A − Cross section area m2

$(\beta_n l)^2$ − End condition constant depends on boundary condition

Plate No..	Plate designation	n	$(\beta_n l)^2$	E	I	ρ	A	l	ω_n	Fn
		1	22.3	2.30E+10	8.55E-10	1493	8.60E-04	2.50E-01	1.40E+03	222.35
1	C_0/90_8_250*250	2	61.7	2.30E+10	8.55E-10	1493	8.60E-04	2.50E-01	3.86E+03	615.20
		3	121	2.30E+10	8.55E-10	1493	8.60E-04	2.50E-01	7.58E+03	1206.46

Table 3. Natural frequency calculations by Euler's and Bernoulli theorems

Experimentation to find natural frequency by FFT analyser

For experimentation data acquisition system with computer software, accelerometer sensor, an instrumentation amplifier used for signal conditioning, a modal hammer and cables along with computer software DEWE Soft 6 is used. The accelerometer sensor is placed on the composite plate to be tested and is excited by a small impact hammer to set it to vibrations. The plate is hanged free in the air and hence produces natural vibrations which are subsequently analysed.

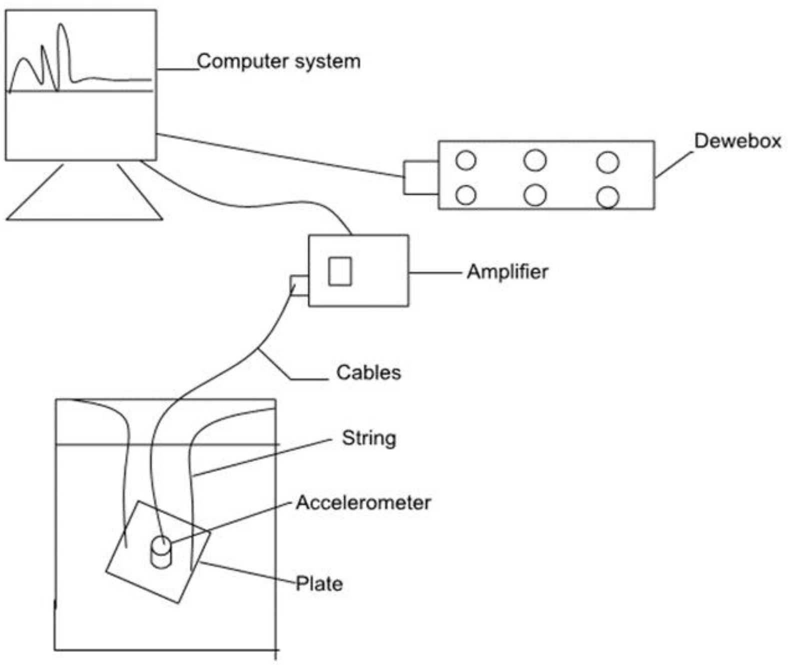


Figure 4 Schematic of Experimental Setup

Figure 4 Plate setup

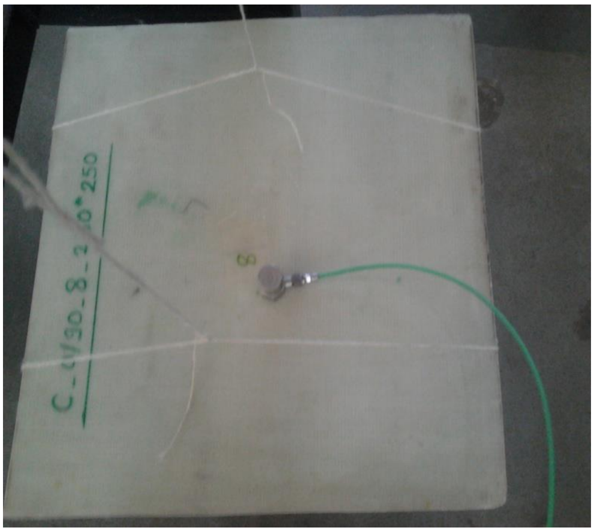
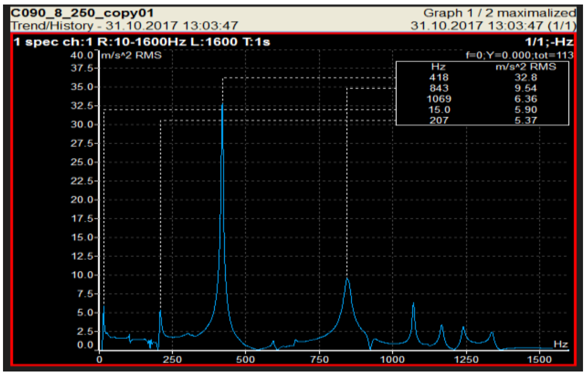
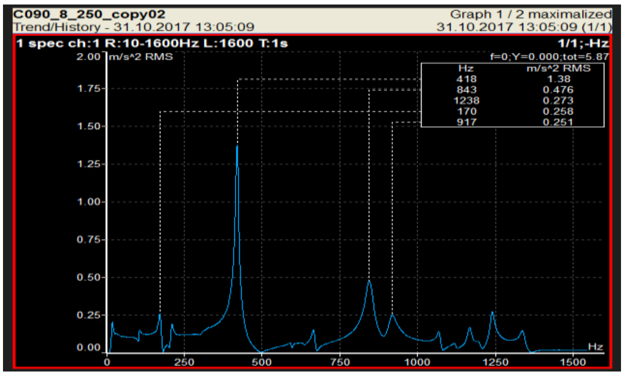


Figure 5 Accelerometer mounting

The experimental data obtained by FFT (Fast Fourier Transform). Figure 6 shows the Frequency domain and Time domain graphs for frequency response function (FRF) for C_0/90_8_250*250 plate





Frequency Domain Graph

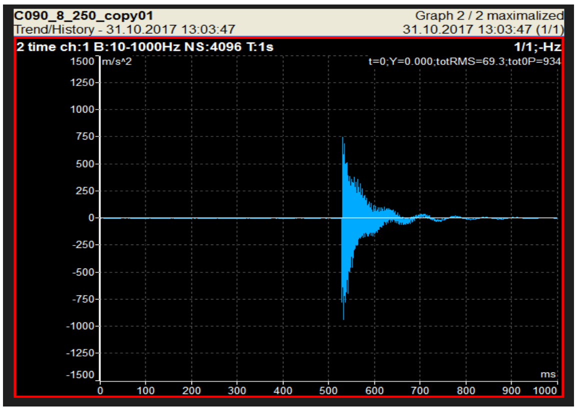


Figure 6 Time Domain Graph

Testing by ANSYS FEA Model

The CAD model and mashing conditions are shown in figure 7 (a), (b)

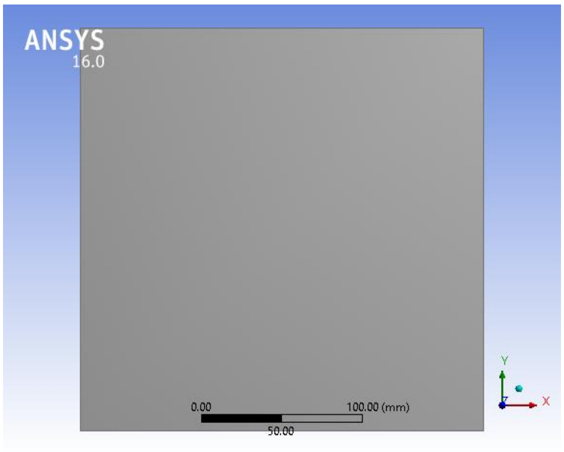


figure 7 (a)Cad Model

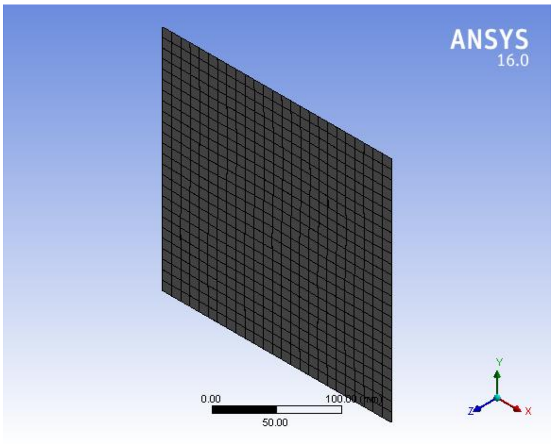


figure 7 (b) Meshing

ANSYS free mesher was used for meshing with 676 nodes and 625 elements

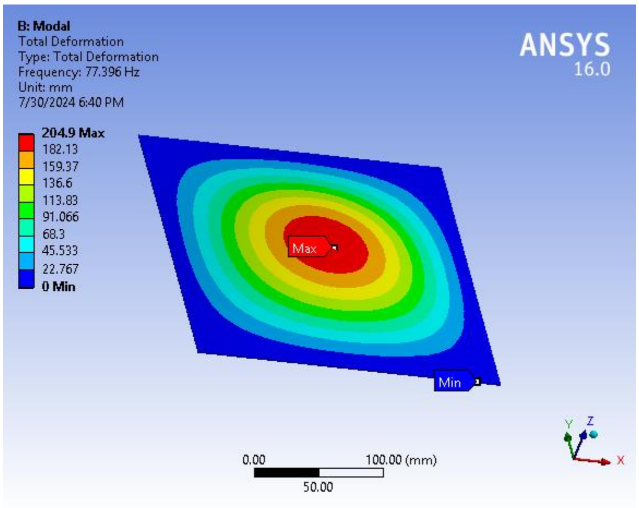


figure 8 Analysis result

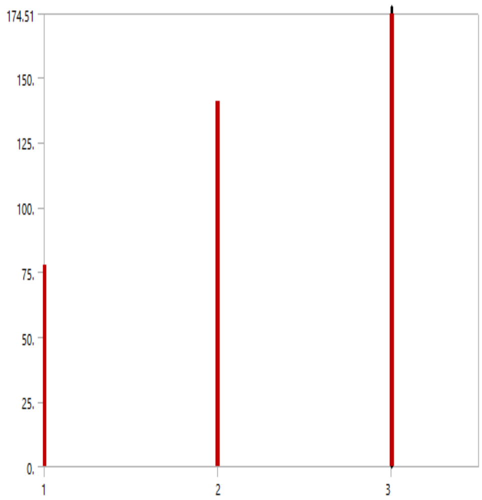


figure 8 bar chart indicates the frequency at each calculated node

The deformation results shown in the figure 8, the maximum deformation observed is 133.72 mm whereas the minimum deformation is observed to be 14.858 mm, the corresponding natural frequency observed at node 1, 2 & 3 are 77.396, 140.94 & 174.15 Hz respectively.

Analytical results of Natural frequency are discussed subsequently. The corresponding natural frequency observed at node B1, B2 and B3 are 77.396, 140.94 and 174.15 Hz respectively and shown in table.

Table 4 comparison of theoretical and analytical results of composite C_0/90_8_250*250

Plate	Node no.	Theoretical Frequency (Hz)	Analytical Frequency (Hz)	Error (%)
C_0/90_8_250*250	B1	77.90	77.396	0.646983
	B2	141.28	140.94	0.240657
	B3	175.193	174.15	0.389856

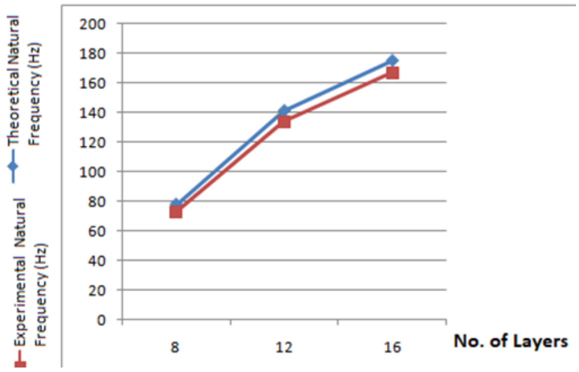


figure 9 Comparison of natural frequency of nodes B1, B2 and B3

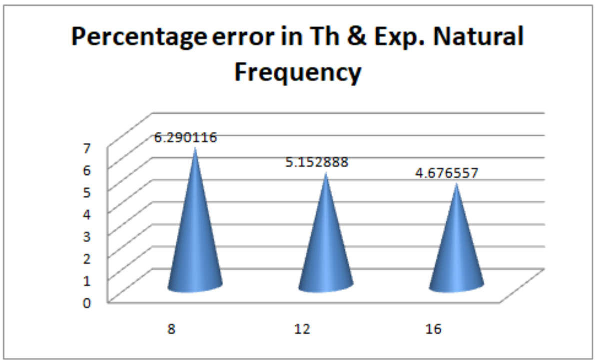


Figure 10 Percentage error between theoretical and experimental natural frequency

The graph of Natural frequency versus no. of layers depicts as Natural frequency increases with increase in no. of layers. Graph shows the relationship between theoretical and experimental natural frequencies. Increasing number of layer stiffness increases and after certain limit natural frequency of increased number of layers' plate decreases as per theory implications.

It is observed that the maximum percentage error is 6.29 % and the Minimum percentage error is seen to be 4.67% well below 10% thereby validating the results as the theoretical – experimental and analytical results are in close agreement.

Comparison of Theoretical and Experimental Results :

Following are the results obtained by theoretical and experiment analysis for three number of modes for various plates.

Table 5 Theoretical and Experimental Frequency for C_0/90_8_250*250

Plate	Node	Frequency (Theory) (Hz)	Frequency (Experimentation) (Hz)	Error (%)
C_0/90_8_250*250	B1	222.34	204	8.24
	B2	615	663	7.8
	B3	1206	1248	3.48

Comparison of Experimental and Simulation Results

Table 6 Experimental and Simulation Frequency for C_0/90_8_250*250

Plate	Node	Frequency (Theory) (Hz)	Frequency (Experimentation) (Hz)	Error (%)
C_0/90_8_250*250	B1	204	210.7	3.28
	B2	663	618.0	6.78
	B3	1248	1197	4.08

Discussion on Results :

For free-free boundary conditions, a data collecting device measures the natural frequencies of glass/epoxy composite plates made of woven fibre. The number of layers and the plate's aspect ratio are two distinct criteria. The inherent frequencies of the plates are measured using the FEA-developed tool. A comparison is made between simulation studies, experimental values, and theoretical results. As seen in the tables, the natural mode of frequency in experimental results can occasionally vary within a range. An approximate agreement with the FEM-based program is demonstrated. The percentage error between the experimental value and the programmed value falls as the mode no rises. However, there is a reasonable variation in the compared outcomes.

The difference between experimental and simulation values are observed due to the specimen is often dog-bone shaped in size. Since the sample cut from the plate differed from the plate utilised in the vibration testing scenario, there could be variations in the plate's elastic characteristics. Tensile characteristics might change depending on the testing environment, speed, and specimen preparation. Because of a diamond-shaped hole where slippage occurred, the current specimens were unable to align in the middle of the jaw. One side of the jaw was fastened with specimens. Therefore, there is a possibility that the elastic modulus (Young's modulus) will drop. Variances in test specimen thickness result in variances in the specimens' surface volume ratios, which might affect the test outcomes. It could also work well to decrease the specimens' cross-sectional area.

CONCLUSION :

Using a data gathering system, the glass/epoxy laminated composite plates are produced and modal testing is carried out for free-free boundary conditions. FFT is used to get frequency response functions. The consequences of various factors, such as the number of layers and aspect ratio, are demonstrated through quantitative data. The theoretical deductions and the program estimation correspond very closely with the experimental frequency data. The error percentage between the ANSYS package and the experimental value is within 15%. The discrepancy is most likely caused by uncertainty in elastic characteristics as well as other factors mentioned. It is discovered that, under the Free-free boundary condition, the natural frequency of the plate rises as the aspect ratio increases. Natural frequency has grown along with the number of layers.

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