



## Estimation of Modal Damping in Laminated Composites through Modal Testing

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**Abstract:** Damping in laminated composite materials is usually a function of many parameters including the volume fraction of the fibers, fiber diameter and fiber orientation relative to the axis of loading. Experimental analysis of the damping of unidirectional glass fiber and carbon fiber composites was carried out. Composite laminate were made using the traditional hand-lay-up process. Experimental dynamic tests were carried out using specimens with different fiber orientations ( $0^\circ, 45^\circ, 90^\circ$ ) and two different boundary conditions (free free and fixed free). Traditional "Strike Method" is adopted which consists of an accelerometer with 4-channel FFT analyzer, impulse hammer to obtain the response of the specimen under test.

**Keywords:** Damping, Frequency, Modal Testing, FRP, Matrix.

### I. Introduction

A large variety of fibers is available as reinforcement for composites the desirable characteristics of most fibers are high strength, high stiffness and relatively low density. Glass fibers and Carbon fibers are the most commonly used one in low to medium performance composites because of their high tensile strength and low cost. Literature published on vibration damping, Bert [1] and Nashif et al [2] had done survey on the damping capacity of fiber reinforced composites and found that composite materials generally exhibit higher damping than structural metallic materials. Suarez et al [3] has utilized random and impulse techniques for measurement of damping in composite materials. The random and impulse techniques utilize the frequency-domain transfer function of a material specimen under random and impulse excitation. Gibson et al [4] utilized the modal vibration response measurements to characterize, quickly and accurately the mechanical properties of fiber-reinforced composite materials and structures. Koo KN et al. [5] studied the effects of transverse shear deformation on the modal loss factors as well as the natural frequencies of composite laminated plates by using the finite element method based on the shear deformable plate theory. evaluated damping of unidirectional fiber composites, orthotropic composites and laminates using beam test specimens and an impulse technique. From the above literature, it can be observed that much of the work on damping is limited to structural damping on single fiber system. Hence, this work is extended to different fiber system and also to study the influence of boundary conditions on the modal damping of laminated composites.

### II. Experimental Programme

#### A. Materials Required for Fabrication of Plates:

The constituent materials used for fabricating the laminates are epoxy/glass and Carbon/epoxy fiber plates as reinforcement, Epoxy as resin, Hardener as catalyst (10% of the weight of epoxy), Polyvinyl alcohol as a releasing agent.

#### B. Fabrication Procedure:

The composite plate specimens used in this research were made from 00/900 unidirectional glass fiber with epoxy matrix. Specimens were fabricated by hand layup technique. The percentage of fiber and matrix has taken as 50:50 in weight for fabrication of the plates. A flat plywood rigid platform is selected. A plastic sheet i.e. a mould releasing sheet was kept on the plywood platform and a thin film of polyvinyl alcohol is applied as a releasing agent by use of spray gun. Any air which may be entrapped was removed using steel rollers. The process of hand lay-up was the continuation of the above process before the gel coat had fully hardened. After completion of all layer, again a plastic sheet was covered the top of last ply by applying polyvinyl alcohol inside the sheet as releasing agent. Finally, a laminated sheet (both Glass & Carbon) of size 500mm\*500mm was obtained from the above process, then the specimen size of 150mm\*150mm for modal testing was prepared

### C. Experimental Setup and Test Procedure for Free Vibration Test:

To simulate free boundary conditions, all the four edges of the plate are suspended freely in a frame using a flexible string as shown in Figure 1. The plate was excited in a selected point by means of Impact hammer (Model2302-5), fixed on the hammer. The resulting vibrations of the specimens on the selected point were measured by an accelerometer mounted on the specimen by means of bees wax. A vibration test setup which includes accelerometer, impact hammer (endeveco-2302-5), 4-channel FFT analyzer along with ME-scope data acquisition software for analysis was used and is as shown in the figure-1

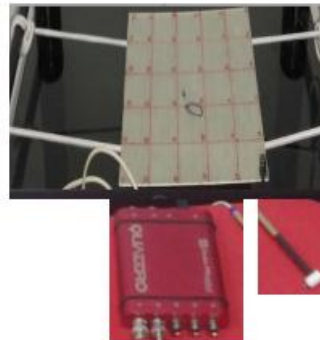


Fig. 1: Modal test set up

36 grid points were marked in order to excite the specimen for 5 trails & average are recorded for further analysis is shown in figure 2

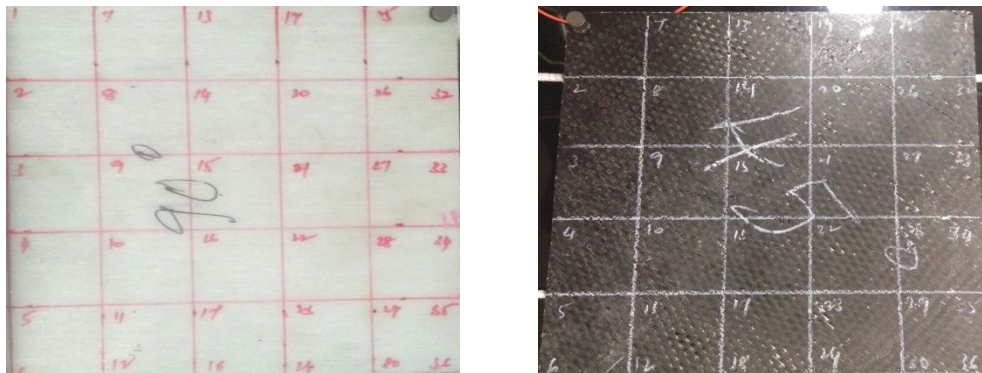


Fig 2 shows 36 grid points marked in laminated composites.

## III. Modal Testing

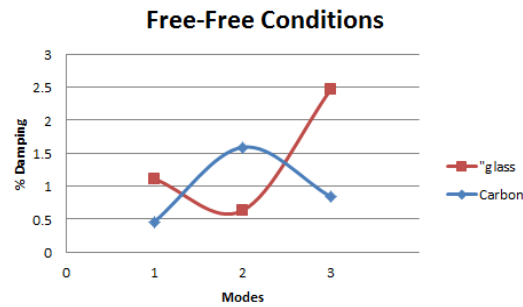
### A. Impact Hammer Modal Testing

An ideal impact to a structure is a perfect impulse, which has an infinitely small duration, causing constant amplitude in the frequency domain this would result in all modes of vibration being excited with equal energy. The impact hammer test is designed to replicate this; however, in reality a hammer strike cannot last for an infinitely small duration, but has a known contact time. The duration of the contact time directly influences the frequency content of the force, with a larger contact time causing a smaller range of bandwidth. A Impact load cell is attached to the end of the hammer to record the force. Impact hammer testing is ideal for small light weight structures; however as the size of the structure increases issues can occur due to a poor signal to noise ratio

## IV. Experimental Results:

Table 1: Free-Free condition.

| Specimen type |      | 0 degree  | 45 degree | 90 degree |
|---------------|------|-----------|-----------|-----------|
| E Glass       | Mode | % Damping |           |           |
|               | 1    | 1.11      | 0.362     | 0.421     |
|               | 2    | 0.633     | 0.657     | 1.55      |
|               | 3    | 2.47      | 1.72      | 0.916     |
| E Carbon      | 1    | 0.463     | 0.362     | 0.421     |
|               | 2    | 1.59      | 0.657     | 1.55      |
|               | 3    | 0.838     | 1.72      | 0.916     |



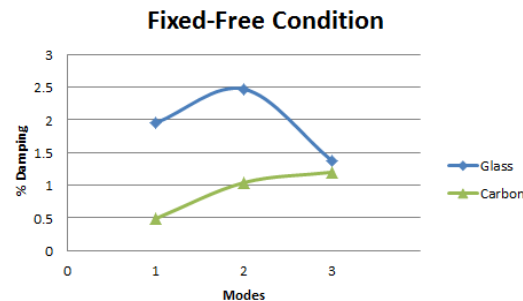
**Graph 1 shows  $0^0, 45^0, 90^0$ , orientations for free-free condition, % Damping V/S Mode number**

Variation of damping ratio with respect to fibre orientation is shown in table.

1.  $0^0$  - It was observed that in free-free condition, the damping ratio for mode 1 (flexural), in case of glass is 58.28% more as compared to carbon fiber for the same condition. This indicates, Glass fiber is more suitable for flexural vibration in free condition, similarly it can be observed carbon seems to be excellent in torsional mode (mode II) for free-free conditions.
2.  $45^0/90^0$  - It was observed that, the damping ratio for mode 1,2 & 3 was same for free-free condition.

**Table 2: Fixed-Free condition.**

| Specimen type | Mode | $0^0$ | $45^0$ | $90^0$ |
|---------------|------|-------|--------|--------|
| E Glass       | 1    | 1.95  | 0.86   | 1.27   |
|               | 2    | 2.47  | 1.65   | 1.65   |
|               | 3    | 1.37  | 0.62   | 2.88   |
| E Carbon      | 1    | 0.49  | 1.36   | 0.856  |
|               | 2    | 1.04  | 2.05   | 1.3    |
|               | 3    | 1.2   | 0.823  | 1.9    |



**Graph 1 shows  $0^0, 45^0, 90^0$ , orientations for fixed-free condition, % Damping V/S Mode number**

Variation of damping ratio with respect to fibre orientation is shown in table.

1.  $0^0$  - It was observed that in fixed free condition, the damping ratio for mode 1 (flexural), in case of glass is 74.87% more as compared to carbon fiber for the same condition. This indicates, Glass fiber is more suitable for flexural vibration in fixed condition.
2.  $45^0$  - It was observed that in fixed free condition, the damping ratio for mode 1 (flexural), in case of carbon is 51.8% more as compared to glass fiber for the same condition. This indicates, Carbon fiber is more suitable for flexural vibration in fixed condition.
3.  $90^0$  - It was observed that in fixed free condition, the damping ratio for mode 1 (flexural), in case of glass is 32.5% more as compared to carbon fiber for the same condition. This indicates, Glass fiber is more suitable for flexural vibration in fixed condition.

## V. Conclusions

Experimental Modal Testing of glass fiber and carbon fiber composite specimens with 2mm thickness with two different boundary conditions (Free-Free & Fixed-Free Conditions) was investigated and the results are tabulated. And it was observed that the damping ratio of glass fiber  $0^0, 45^0, 90^0$  orientations under free-free conditions, 0 degree orientation exhibits better damping in flexural condition compared to  $45^0$  &  $90^0$  orientation. Similarly under fixed condition  $0^0$  orientation exhibits better damping compared to  $45^0$  &  $90^0$  orientation. In case of carbon fibers the damping ratio of  $0^0, 45^0, 90^0$  orientations under free-free and fixed free conditions, 45 degree orientation exhibits better damping in torsional mode compared to  $0^0$  &  $90^0$  orientation. For the laminated composite specimens, the change in the vibration properties is more significant with change in boundary conditions with respect to their orientations, but it is less sensitive for thickness consideration. The adoption of modal test seems to be very simple, effective and justified. Influence of boundary conditions and fiber orientation seems to play an important role in estimation of modal damping. Thus, it can be concluded that evaluation of modal damping through experimental modal technique is very simple and effective method.

## VI. References

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## VII. Acknowledgements

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