

# Study on the influence of design parameters on the damping property of glass fiber reinforced epoxy composite

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**Abstract.** Fiber reinforced composites are widely used in industrial applications due to their high strength, light weight and ease in manufacturing. In applications such as automotive, aerospace and structural parts, the components are subjected to unwanted vibrations which reduce their service life, accuracy as well as increases noise. Therefore, it is essential to avoid the detrimental effects of vibrations by enhancing their damping characteristics. The current research deals with estimating the damping properties of Glass fiber reinforced epoxy (GFRE) composites. Processing of the GFRE composites is carried out using hand-lay technique. Various design parameters such as number of glass fiber layers, orientation of fibers and weight ratio are varied while manufacturing GFRE composites. The effects of variation of these design parameters on damping property of GFRE composites are studied extensively.

## 1. Introduction

The use of fiber reinforced polymer (FRP) matrix composites is increasing due to inherent advantages of high strength, easy manufacturing techniques, light weight, high damping, etc. These found wide industrial applications such as automotive, aerospace, marine, medical, sports, machine tools and various other structures [1]. Further, polymer matrix composites can be produced in any complex shape requiring less energy. Examples of such polymers are epoxy, polyester, urethane, etc. However, the most commonly used polymer is epoxy which is usually reinforced with glass fibers and is specifically used for structural applications. In such applications it is essential to know the damping property of the composites.

Chandra et al. [2, 3] have mentioned in their work that damping in composite materials is different from that of conventionally used metals. They reported that the various ways in which energy is dissipated from FRP composites are-viscoelastic behaviour of matrix or fibers, interphase damping, visco-plastic damping and thermo-elastic damping. They further used an integrated finite element method or strain energy approach to determine the loss factor for two and three phase composite with interfacial discontinuity. They have also carried out research on the theory of damping mechanism of composite materials such as micromechanical, macro-mechanical and viscoelastic. Srinivas et al. [4] have studied the mechanical and chemical properties of various natural fiber reinforced composites such as jute, hemp, kenaf, flax, etc. and compared the results with synthetic fibers. Suresha et al. [5] have demonstrated that filling glass epoxy composite with graphite particulates improves the mechanical properties such as hardness, tensile strength, tensile modulus, percentage elongation as well as wear resistance. Deogonda et al. [6] have studied the effect of reinforcement of TiO<sub>2</sub> and ZnS particles on the mechanical properties of GFRE composites. They found that with increase in ZnS



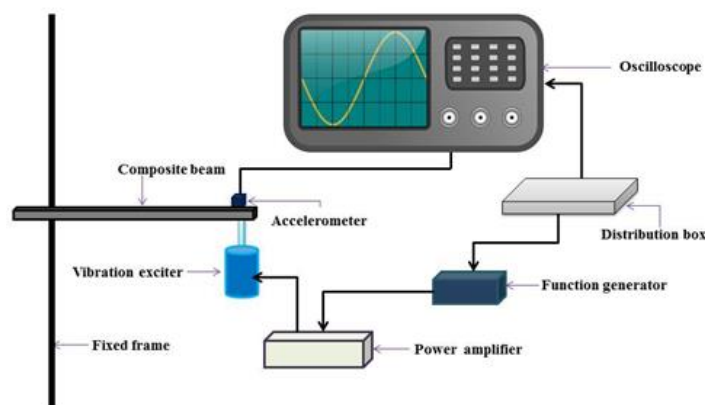
filler content, the mechanical properties of composites increases compared to the other combination of composites. Biswas et al. [7] have shown that the erosion characteristics of glass and bamboo fiber epoxy composites improve when reinforced with red mud particulates.

Therefore, the current research focuses on studying the effect of various design parameters on the damping property of glass fiber reinforced epoxy (GFRE) composite. The various design parameters that are taken into account are fiber loading, fiber orientation and number of glass fiber layers.

## 2. Experimentation details

The experimental study comprises of estimating the damping properties of GFRE composite. Woven glass fiber mat is used with epoxy resin and hardener having trade-name Bisphenol-A-Diglycidyl ether and tri-ethylene tetra-amine respectively. The matrix material comprises of epoxy and hardener, mixed in the weight ratio of 10:1. The wet lay-up technique is used to fabricate the GFRE composites as the process is simple and inexpensive. This open mould process is suitable for fabricating any variety and size of polymer matrix composites. The process is easy compared to other manufacturing processes as it doesn't require any complex tools or instruments and can also be done at normal environmental conditions. Mould releasing agent such as sheet and spray are used to cover the surface of the mould. Care is taken to ensure thorough mixing of the epoxy and hardener as well as proper matrix coating on the glass fiber surface. The fiber surface is frequently rolled with a hand roller to remove any trapped gas bubble or tangled glass fibers. Each cast composite is first cured by applying a load of about 400 N for a period of 24 hours and then cured in air for 24 hours. Utmost care is taken to maintain homogenous distribution of fiber and matrix material and to avoid any defect in the final composite structure.

Test samples of 350×50×5 mm dimensions are cut from the cured GFRE samples using a diamond cutter. An experimental setup consisting of a heavy and rigid frame has been prepared to hold the fixed end of the cantilever beam as shown in Figure 1. In order to ensure negligible support damping, the composite beams are stiffly fixed to the frame in order to avoid any rotation and achieve rigid cantilever condition. Vibration exciter is placed below the free end of the cantilever beam to impart forced excitations to the beam. A contact type accelerometer is placed on the free end to sense the signals and supply it to the digital storage oscilloscope (DSO). Function generator is used to apply required loading frequency for excitations.



**Figure 1.** Schematic diagram of the experimental setup.

Logarithmic decrement method is used to calculate the damping parameters from amplitude versus time plot obtained from DSO. The following equations are used to calculate the damping ratio and natural frequency from the curves.

$$\delta = \frac{1}{n} \ln\left(\frac{x_1}{x_{n+1}}\right) \quad (1)$$

$$\zeta = \frac{\delta}{\sqrt{(4\pi^2 + \delta^2)}} \quad (2)$$

$$\omega_d = \frac{2\pi}{\Delta T} \quad (3)$$

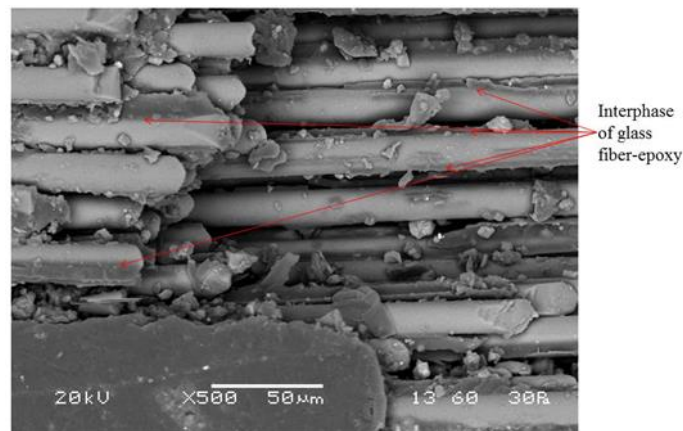
$$\omega_n = \frac{\omega_d}{\sqrt{1 - \zeta^2}} \quad (4)$$

where  $\delta$ ,  $\zeta$ ,  $\omega_d$ ,  $\omega_n$ ,  $x_1$ ,  $x_{n+1}$ ,  $\Delta T$  and  $n$  denotes logarithmic decrement, damping ratio, damped natural frequency, natural frequency, peak amplitude of first cycle, peak amplitude of  $(n + 1)^{\text{th}}$  cycle, time period between two successive amplitude peaks and number of cycles respectively. The current research focuses on the effect of various parameters such as fiber orientation, fiber loading and number of fiber layers on the damping property of GFRE composite.

### 3. Results and discussions

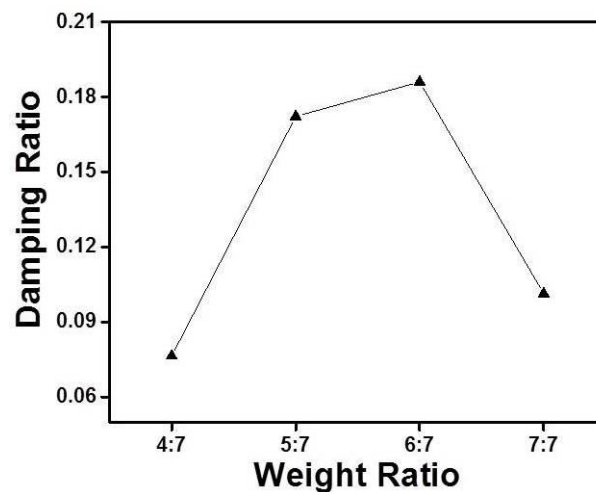
#### 3.1. Effect of weight ratio or fiber loading

The ratio of weight of fibers reinforced to the weight of resin is known as fiber loading. The damping of epoxy matrix is quite significant compared to glass fibers. This is due to the visco-elastic nature of epoxy which helps in dissipating energy. Moreover, the interphase region adjacent to the fiber surface also contributes in energy dissipation. Figure 2 illustrates the SEM (scanning electron microscope) micrographs of GFRE composites of 7:5 weight ratio of glass fiber to epoxy at 500x magnification. In the figure, the interfacial region between the fiber and the matrix is indicated using red arrows.



**Figure 2.** SEM micrographs of GFRE composite with 7:5 weight ratio.

The influence of fiber loading on the damping behavior of GFRE composites is evaluated. For this purpose, distinctive weight ratio of 7:7, 7:6, 7:5 and 7:4 of glass fibers and blend of epoxy and hardener is used for fabricating GFRE composites. The number of glass fiber layers used for fabricating the GFRE composites is 12. For performing damping experiments, 300 mm cantilever length of GFRE is used with excitation frequency of 5 Hz. Amplitude vs. time plots are obtained from experimental analysis and logarithmic decrement method is used to find out the damping ratio and natural frequency. The damping ratio for each weight ratio is calculated and plotted as shown in Figure 3.



**Figure 3.** Plot of damping ratio versus weight ratio of GFRE composites.

The dissipation of energy in FRP composites occur either due to the viscoelastic nature of the matrix or due to the interfacial region between the fiber and the matrix. From *Figure 3*, it is evident that damping ratio increases with increase in the percentage of epoxy content up to 46% (approx.) i.e., 7:6 weight ratio and then decreases. The GFRE composite with 50 weight % of matrix has the least damping. The increase in damping of GFRE composites up to 46% of matrix is due to dissipation of energy through epoxy matrix. However, in case of 50% epoxy or fiber content, the damping is decreased due to reduced weight fraction of glass fibers as compared to other 3 types of GFRE composites. In this case, the damping due to fiber-matrix interface predominates the damping due to viscoelastic matrix.

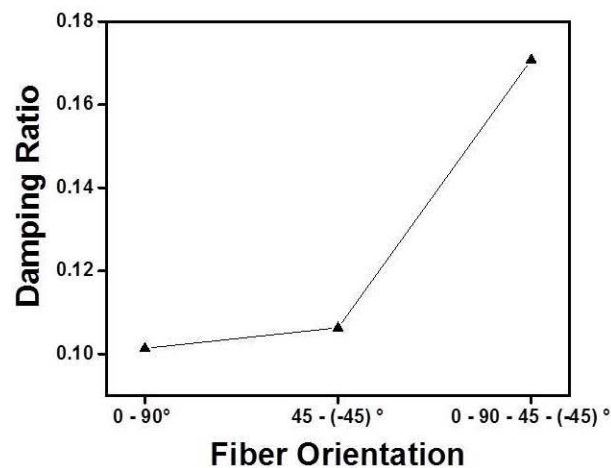
### 3.2. Effect of woven fiber-mat orientation

A total of three samples were made for the experiment of damping. The materials used for making these samples are the glass fiber and epoxy resin with proper hardener. Each sample has 12 layers of the glass fiber. The weight of glass fiber was measured and according to that the weight of epoxy-hardener mixture was decided. As the weight ratio taken was 1:1, the epoxy-hardener weight is same as glass fiber. The epoxy and hardener were mixed in the ratio of 10:1.

The difference in these samples is the orientation of the glass fibers. The orientation has been changed while fabricating these GFRE composites. The configuration of these samples is:

- 0 – 90 °orientation
- 45 – (-45) °orientation
- 0 – 90 – 45 – (-45) °orientation

To measure damping, composite cantilever beams of length 300 mm are used and the tests are performed at 5 Hz loading frequency. Amplitude vs. time plots obtained from the digital oscilloscope is used to calculate the damping ratios of the three composite samples. The damping ratio for the three composite of different fiber orientations is calculated and is plotted in *Figure 4*.

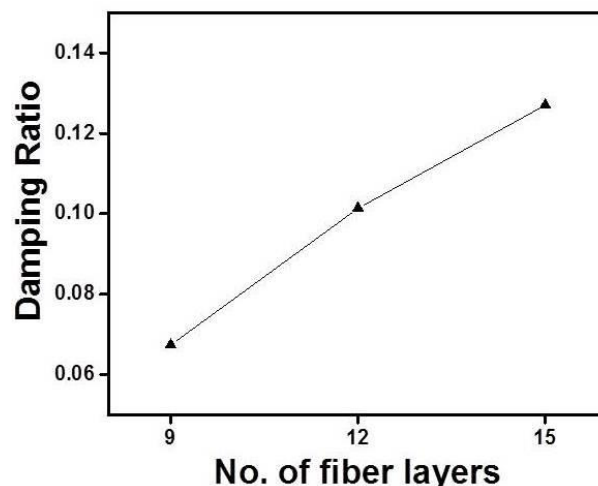


**Figure 4.** Plot of damping ratio versus fiber orientation of GFRE composites.

It can be seen from Figure 4 that the damping ratio is highest for 0–90–45–(–45) ° cross ply laminate. The angle orientation has lowered the damping value of 0–90 ° laminate compared to 45–(–45) ° orientation though, the difference is quite negligible. However, in case of 0–90–45–(–45) ° orientation, the energy dissipation is more due to cross-ply laminate arrangement which facilitates higher damping ratio.

### 3.3. Effect of number of fiber layers

The effect of number of fiber layers or the thickness of composite laminate on damping of composites is assessed by determining the damping ratio of samples prepared by stacking woven glass fiber layers at 0 - 90 ° orientation with distinct number of glass fiber layers as 9, 12 and 15. The weight ratio of 1:1 of glass fiber to the epoxy-hardener mixture is used. A cantilever length and excitation frequency of 300 mm and 5 Hz respectively is maintained. Logarithmic decrement method is used to calculate the damping ratio from amplitude vs. time plots obtained from experiments. The damping ratio of composite laminates for different number of glass fiber layers is shown in Figure 5.



**Figure 5.** Plot of damping ratio versus number of fiber layers of GFRE composites.

It is seen that as the number of woven fiber layers increases, the damping ratio of the cantilever beam increases. The GFRE composite sample with 15 layers of woven fiber has maximum damping ratio. The increase in number of glass fiber layers facilitated the increase in dissipation of vibrational energy.

Moreover, the increased epoxy matrix content too enables better damping. Therefore, the damping ratios of the GFRE composites have increased with increasing fiber layers.

#### 4. Conclusions

The experimental study of the effect of various design parameters of GFRE composites on the damping property leads to the following conclusions:

The damping ratio of GFRE composites increases with increase in weight of fiber matrix up to 46% and then found to decrease. The increase in damping is due to the dissipation of energy via the visco-elastic epoxy while the decrease is due to reduced weight fraction of glass fibers.

The damping ratio of GFRE composite with 0 – 90 – 45 – (-45) ° orientation has highest damping ratio compared to 45 - (-45) ° and 0 - (90) ° orientations due to cross-ply laminate arrangement enabling better energy dissipation.

The damping ratio of GFRE composites increases with increase in number of glass fiber layers.

#### 5. References

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