

Analysis of Damped Free Vibration on Glass-Epoxy Composites with Aluminium Powder as Filler

Rueben Obed D'Souza^{1*}, Yajnesha P Shettigar², Shreeganesh Thantri³, Prajwal A Suvarna⁴, Raveendra Naik⁵ and Surendra M⁶

^{1,2} Assistant Professor, Department of Mechanical Engineering, Mangalore Institute of Technology and Engineering, Moodabidri

^{3,4,5,6} Under Graduate Students, Department of Mechanical Engineering, Mangalore Institute of Technology and Engineering, Moodabidri

* rueben.dsouza@yahoo.com

Abstract: Glass-Epoxy Composites are having a wide range of applications due to its light weight and low cost. This paper deals with the fabrication of Glass-Epoxy composites having a composition of 70-30% with Aluminium powder as a filler material. The percentage of aluminium is varied by 2%, 4% and 6% by volume. Aluminium due to its high strength to weight ratio finds its application in many areas. The composite plates are fabricated as per ASTM standards and Tensile test and 3-point bending tests are carried out to determine the mechanical properties of the composite. Modal Analysis is done using Fast Fourier Transform and the analytical results are obtained from Nastran. The experimental and Analytical results are compared with each other.

1. Introduction

Composites are one of the most advanced and versatile engineering materials known to men. Evolution in the field of material science has given birth to these wonderful fascinating materials. Composites are heterogeneous in nature and formed by the assembly of two or more materials with reinforcing fibres or fillers and a compactable matrix. The matrix may be ceramic, metallic or polymeric in origin. This gives the composite its shape, environmental tolerance, surface appearance and overall durability while most of the structural loads are carried by the fibrous reinforcement thus providing macroscopic stiffness and desired strength. A composite material provides superior and unique physical and mechanical properties as it combines the most enticing properties of its constituents while repressing their least desirable properties. At present composites play a very important role in automobile industry, aerospace industry and various other engineering applications since they exhibit outstanding weight and strength to weight ratio. High performance intransigent composites made from graphite, glass, boron, silicon carbide fibres or Kevlar in polymeric matrices have been studied broadly because of their application in space vehicle technology and aerospace.

The composites are classified based on the matrix material which creates the continuous phase. They are categorised as Metal Matrix Composites (MMC's), Ceramic Matrix Composites (CMC's) and Polymer Matrix Composites (PMC's). Of these the polymer matrix composites are much simpler to fabricate than Metal Matrix Composites and Ceramic Matrix Composites since they have a relatively low processing temperature for fabricating.

PMC's generally consist of synthetic fibres like nylon, carbon, glass or rayon embedded in a polymer matrix which tightly binds the fibres. Generally, the fibres make up to about 60% of polymer matrix composite by volume. The fibrous reinforcing component of composites may consist of relatively short fibres or thin continuous fibre segments. Fibres with high aspect ratio i.e.; length to diameter ratio are used when using short fibre segments. Continuous fibre reinforced composites are required for high performance structural applications. The specific strength and specific stiffness of continuous carbon fibre reinforced composites can be exceptional to conventional metal alloys. Also composites can be tailored specifically for a particular use by orienting the fibres in different directions. Polymer concretes are widely being used in structural applications. The non-corrosive characteristics and high strength to weight ratio of composite materials like fibre reinforced plastics can be employed to build innovative structures which are desirable as well as economical.

Although composite materials have advantages over conventional metals, they also have some disadvantages. PMC's and other composites tend to be anisotropic; i.e. properties like stiffness, strength etc. are different in different directions. This poses a significant challenge for the designer when using composite materials in structures which have multi directional forces. Forming a strong connection between the different components of composite material is difficult. Development of advanced composite materials that have superior mechanical properties have opened up new horizons in the engineering stream.

Filler materials are used to alter and improve the mechanical and physical properties of composites. They may also be used to reduce costs by scaling down the volume of matrix resin required. There are 2 types of fillers namely conductive filler and extender filler. Conductive fillers are used to increase electrical and thermal conductivity. Extender fillers are used to reduce material costs.

2. Literature Review

Suhas et al. [1] presented a journal on dynamic and stability analysis of delaminated rectangular composite panels. This investigation deals with the study of static, vibration and the dynamic stability of delaminated composite plates by using finite element method. The influence of various geometrical parameters like delamination size, aspect ratio, number of layers etc. have been analysed numerically. N.Nayak et. al. [2] conducted an experiment and numerical investigation on vibration and buckling characteristics of Glass/Epoxy hybrid composite panels. Lamination sequence effects on natural frequencies of vibration & buckling strength of these panels were studied. They concluded that pure carbon fibre plates had more strength in buckling and vibration when compared to hybrid plates.

Xu Lei et. al. [3] studied the effect of woven structures on dynamic mechanical and vibration properties of fabric composite plates. In this study they fabricated five woven structures and conducted bending and vibration tests and found that the stiffness and natural frequency of interlocked structure was higher than laminated plane-weaved woven structure.

S.S. Chavan [4] presented a paper on vibration analysis of composite plates. He studied different mode frequencies for free vibration as per change in aspect ratio, fibre orientation and thickness. He desisted that the natural frequency was low for [45/-45] fibre orientation and it increased for [30/-60] fibre orientation.

Chikkol V. Srinivasa et. al. [5] did an experiment and FE analysis on free vibration of laminated and isotropic composite cylindrical skew panels and examined the effects of skew angle and aspect ratio on natural frequencies. The first three natural frequencies were found to decrease with increase in aspect ratio.

J. Alexander et. al. [6] carried out a study on vibration characteristics of BFRP composites with GFRP composites at different fibre orientations and end conditions. They concluded that BFRP composites have high damping co-efficient & superior vibration characteristics.

Itishree Mishra et. al. [7] conducted an experiment to investigate the free vibration characteristics of Glass/Epoxy composite plates under free-free boundary condition. They studied the effects of

geometrical parameters such as number of layers, fibre orientation and aspect ratio of woven fibre composite plates.

The glass fibre is a bi-directional mat with 0/90° orientation having a mass of 204 gsm. The glass fibre is supplied from Marktech Private Limited, Bangalore. The epoxy is LAPOX 12 and the hardener is polyamine hardener (K6) which is supplied by Yuje Enterprises, Bangalore. The aluminium powder is supplied by J & J Groups, Bangalore. The glass fibre and epoxy are fabricated by volume percentage of 70-30%. The aluminium filler material percentage is varied as 2%, 4% and 6% for the glass/epoxy percentage.

3. Fabrication Methodology

The mould is made of plywood having dimensions of 300×300×3 mm. A plastic sheet is placed in the mould and a thin film of petroleum jelly and coconut oil is applied over it. A sheet of glass fibre having appropriate dimensions is placed over it and epoxy is applied over the sheet of glass fibre. Epoxy is mixed with 10% hardener as well as calculated amount of aluminium filler material. Same procedure is followed for more layers of glass fibre until the required layers are satisfied for the given composition. The excess epoxy and air gaps are removed using a roller. Then a plastic sheet applied with a thin film of petroleum jelly and coconut oil is placed over it and covered. The Hand Lay-Up method is shown in figure 1. A heavy flat rigid metal platform is placed above the mould for compressive purpose. Curing is done for 1 day and the samples are kept in the sun for the next 3 days for drying. Material is cut as per required shapes for testing purpose.

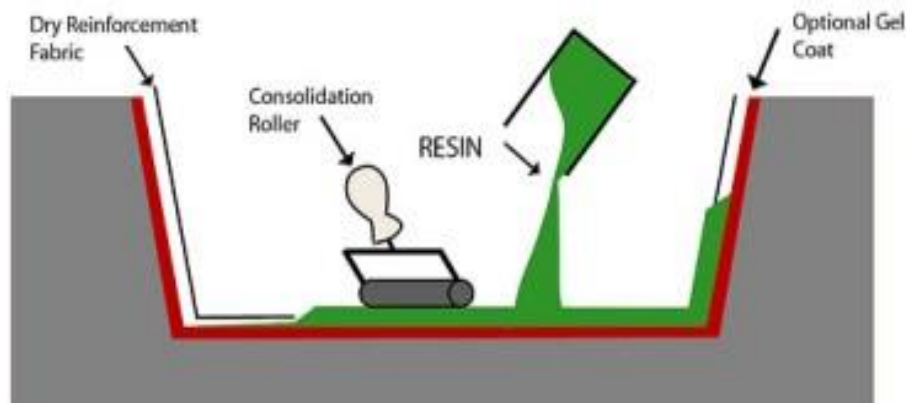


Figure 1. Hand Lay-up Process

Table 1. Details of Fabricated Composite

Volume % of Glass -Epoxy	Volume % of Filler	Volume % of Glass Fibre	Volume % of Epoxy Resin	Number of layers of Glass Fibre	Mass of Epoxy Resin in 'gm'	Mass of Aluminium Filler in 'gm'
70 - 30	2	0.686	0.294	26	129.38	6.48
	4	0.672	0.288	25	126.75	12.96
	6	0.658	0.282	25	124.10	19.44

4. Results and Discussion

4.1 Tensile Test:

A tensile test also familiar as tension test is probably the most basic type of mechanical test that can be performed on a material. Tensile tests are relatively inexpensive, simple and fully standardized. Tension test is a destructive test process that is widely used to furnish basic design information on tensile strength, ductility of the material, yield strength and Young's Modulus. Instron 3366 machine, its tensile test set up and the tensile test specimen as per ASTM D 638.

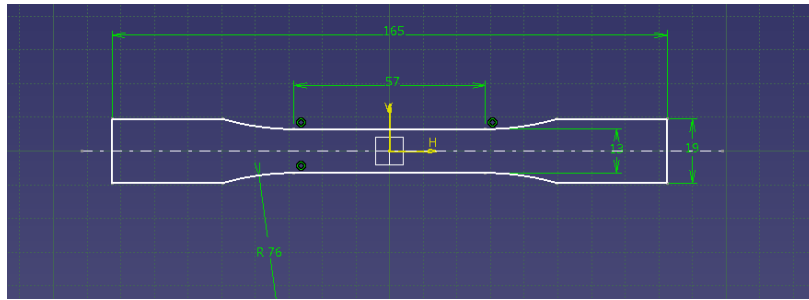


Figure 2. Tensile Specimen Dimensions

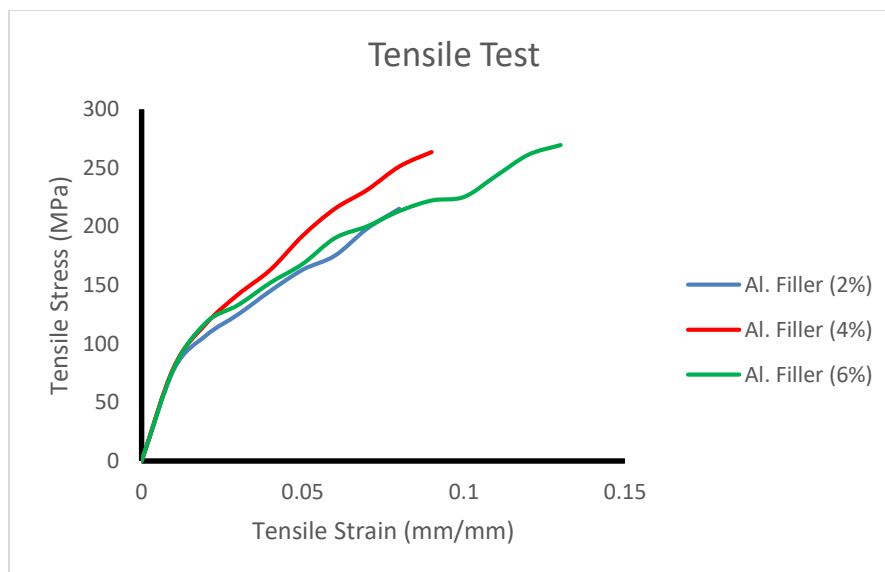


Figure 3. Combined Tensile Behaviour of Glass/Epoxy Composites

The Maximum Load carrying capacity of 70-30% Glass/Epoxy Composite plates with 2%, 4% and 6% Aluminium filler are 10.5KN, 10.7KN and 11KN respectively. The Young's Modulus of 70-30% Glass/Epoxy Composite plates with 2%, 4% and 6% Aluminium filler are 6.35GPa, 6.86GPa and 6.39GPa respectively.

4.2 Bending Test:

Flexural strength also familiar as modulus of rupture, fracture strength or bend strength is a material property outlined as the stress in a material just prior to yielding in a flexure test. It represents the maximum stress experienced within the material at the time of rupture. The flexural test method measures the behavior of materials that are subjected to simple beam bending. With some materials it is also known as transverse test. This provides the values of Young's Modulus, flexural stress and flexural strain.

The Maximum Flexural Load of 70-30% Glass/Epoxy Composite plates with 2%, 4% and 6% Aluminium filler are 67.39N, 68.26N and 87.81N respectively. The Young's Modulus of 70-30% Glass/Epoxy Composite plates with 2%, 4% and 6% Aluminium filler are 26.4GPa, 32.5GPa and 37.8GPa respectively.

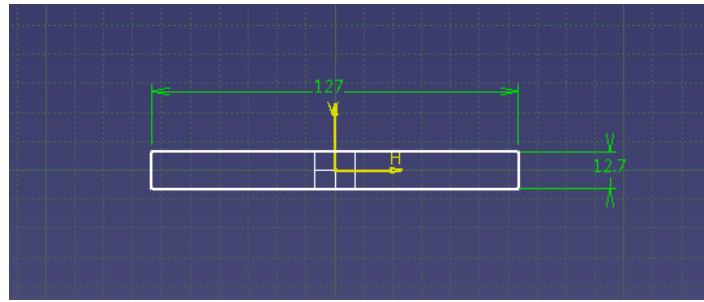


Figure 4. Bending Specimen Dimensions

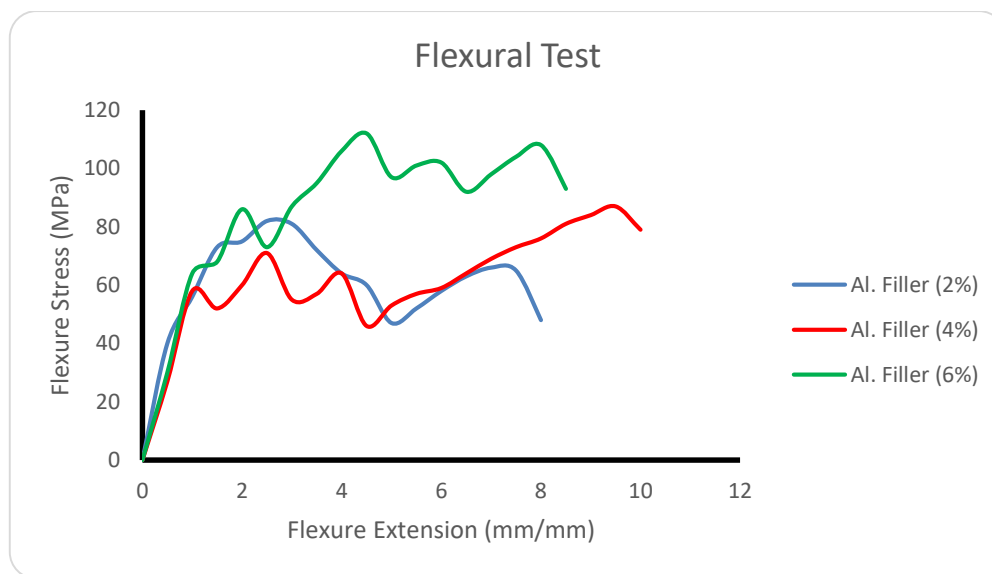


Figure 5. Combined Flexural Behaviour of Glass/Epoxy Composites

4.3 Vibration Test:

The setup of FFT Analyzer includes Accelerometer, Modal Hammer, FFT Analyzer and a system with LAB VIEW software. The LAB VIEW key is connected to the inlet of the system. The end of the vibration specimen which is fixed is excited using an impact hammer of PCB Type and the end that is free is connected to the accelerometer using a wax type glue. The force transducer on the impact hammer measures the input signal. With the help of the analyzer we obtain the output signals frequency range.

The dimensions of the composite vibration specimen for cantilever type boundary condition is 200*20*3mm. the effective length of the specimen is 180mm. For this type of boundary condition one of the end is fixed while the other end is free. The LAB VIEW software will show the output signal on the display of the system. The output signals are obtained as Frequency Response Function (FRF). The results of the LAB VIEW software contain Frequency Vs Phase Time, Frequency Vs Amplitude and Time Vs Amplitude.

The Modal Hammer used is YMC121A100 IEPE Type. Its temperature range varies from -40°C to 121°C. the range of its frequency is 0.5Hz to 8000Hz. Accelerometer response frequency is greater than 25KHz. The size of the accelerometer is 13*22mm.

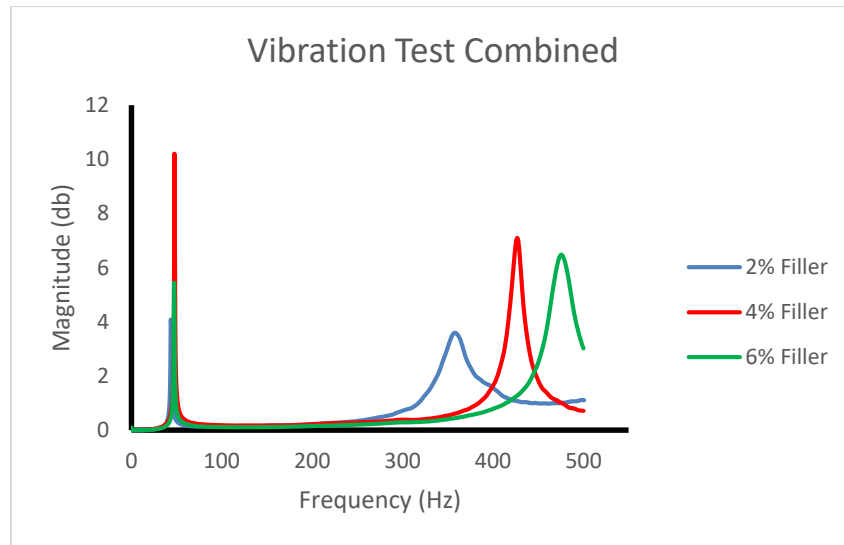


Figure 6. Combined Frequency Vs Magnitude of Glass/Epoxy Composites

The Results were validated using Nx Nastran Femap Software.

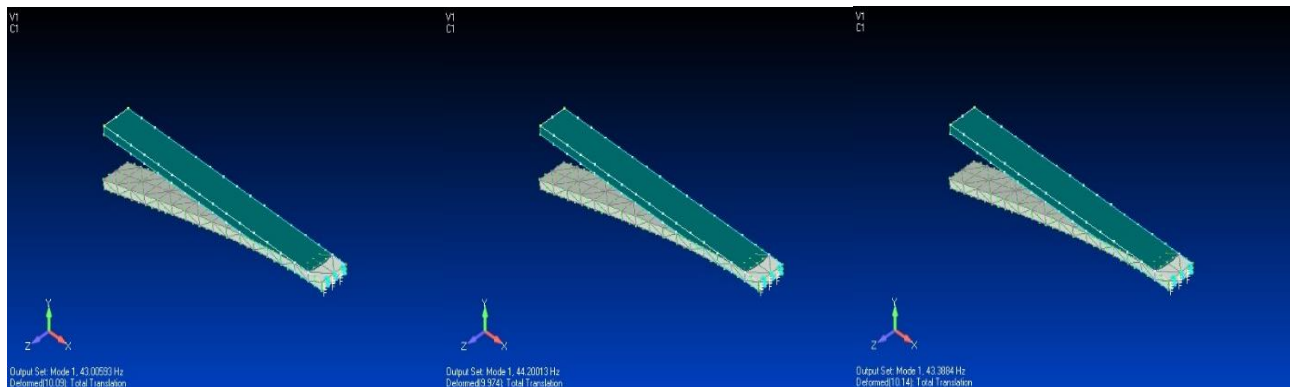


Figure 7. Mode 1 Value of 70-30% Glass/Epoxy Composite with 2%, 4% & 6% Filler

Table 2. Values of Frequency for Mode 1, Logarithmic Decrement and Damping Ratio

Composition of Glass/Epoxy	Frequency for Mode 1 (Hz)	Logarithmic Decrement δ	Damping Ratio ε
70-30% with 2% Al.	43.5	0.062	0.010
70-30% with 4% Al.	47.5	0.059	0.0095
70-30% with 6% Al.	47	0.063	0.010

Table 3. Comparison of Frequency values of Glass/Epoxy Composite Plates of different Compositions

Composition of Glass/Epoxy	Frequency(Hz)			
	Mode 1		Mode 2	
	Experimental	Analytical	Experimental	Analytical
70-30% with 2% Al.	43.5	43.005	358	342.0703
70-30% with 4% Al.	47.5	44.2	427	408.4987
70-30% with 6% Al.	47	43.286	476	437.5154

5. Conclusion

- From Tensile Tests it is clear that 70-30% Glass/Epoxy Composite with 6% Aluminium filler has maximum tensile strength in comparison with 70-30% Glass/Epoxy Composite with 4% and 2% Aluminium filler.
- Flexural Tests shows that 70-30% Glass/Epoxy Composite with 6% Aluminium filler has maximum flexural strength and it reduces for 70-30% Glass/Epoxy Composite with 4% and 2% Aluminium filler.
- From Modal Analysis it is seen that vibration Frequency is maximum for 70-30% Glass/Epoxy Composite with 2% Aluminium filler.
- Modal Analysis makes it clear that Damping ratio is maximum for 70-30% Glass/Epoxy Composite with 2% Aluminium filler and minimum for 70-30% Glass/Epoxy Composite with 4% Aluminium filler.
- From Modal Analysis we observe that Logarithmic Decrement is maximum for 70-30% Glass/Epoxy Composite with 6% Aluminium filler and minimum for 70-30% Glass/Epoxy Composite with 4% Aluminium filler.

References

- [1] Suhas, Dr Prabhakara D L 2013 Dynamic and Stability analyses of delaminated rectangular composite panels *Int J. of Science, Engineering and Technology Research (IJSETR)* **2**(8).
- [2] N. Nayak, Meher S, and Sahu S. K 2013 Experimental and Numerical Study on Vibration and Buckling Characteristics of Glass-Carbon/Epoxy Hybrid Composite Plates *Proc. of Int. Conf. on Advances in Civil Engineering, AETACE*.
- [3] Xu Lei, Wang Rui, Liu Yong, and Li Jin 2011 The Effect of Woven Structures on the Vibration Characteristics of Glass Fabric/Epoxy Composite Plates *Defence Science Journal* **61** 499-504.
- [4] Swapnil Sanjay Chavan 2014 Study on Vibration Analysis of Composite Plate *Int Conference on Multidisciplinary Research & Practice* **1**(4)
- [5] Chikkol Srinivasa V, Yalaburgi Suresh J and Wooday Prema Kumar P 2014 Experimental and finite element studies on free vibration of cylindrical skew panels *Int Journal of Advanced Structural Engineering* **6**(1).
- [6] Alexander J^{*} and Augustine B. S. M 2015 Free Vibration and Damping Characteristics of GFRP and BFRP Laminated Composites at Various Boundary Conditions *Indian Journal of Science and Technology* **8**(12).
- [7] Itishree Mishra & Shishir Kumar Sahu 2012 An Experimental Approach to Free Vibration Response of Woven Fiber Composite Plates under Free-Free Boundary Condition *Int Journal of Advanced Technology in Civil Engineering* **1**(2).