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Evaluation of Modal Damping in FRP Based Laminated Composites through Modal Testing

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Abstract- The main source of damping in laminated composite materials arises from the inelastic nature of the matrix and the relative slipping at the fiber/matrix interfaces. 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. Also the magnitude and frequency of the applied load and many environmental factors should be mentioned. Since the complex phenomenon of damping is difficult to incorporate into the structural dynamic analysis of laminated plates, a modal damping approximation is employed here. Various methods have been presented to obtain the modal damping of a laminated composite. In this paper, classical modal testing of bi-woven laminates under various boundary conditions and analysis of the damping is carried out. Laminates made of Glass and Graphite fibers with epoxy resin as matrix is used in modal testing. Traditional "Strike Method" is adopted which consists of impulse hammer and accelerometer with 4-channel FFT analyzer to obtain the response of the specimen under test. Results obtained from both laminates are compared and it is observed that damping properties of graphite is more dominant than glass laminates.

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

I. INTRODUCTION

The three essential parameters that determine the dynamic responses of a structure are mass, stiffness and damping. Mass and stiffness are associated with storage of energy. Damping results in the dissipation of energy by a vibration system. For a linear system, if the forcing frequency is the same as the natural frequency of the system, the response is very large and can easily cause dangerous consequences. In the frequency domain, the response near the natural frequency is "damping controlled". Higher damping can help to reduce the amplitude at resonance of structures. Increased damping also results in faster decay of free vibration, reduced dynamic stresses, lower structural response to sound, and increased sound transmission loss above the critical frequency.

There is much literature published on vibration damping. ASME published a collection of papers on structural damping in 1959 [1]. Lazan's book published in 1968 gave a very good review on damping research work, discussed different mechanisms and forms of damping, and studied damping at both the microscopic and macroscopic levels [2]. This book is also valuable as a handbook because it contains more than 50 pages of data on damping properties of various materials, including metals, alloys, polymers, composites, glass, stone, natural crystals, particle-type materials, and fluids. The effects of thickness and delamination on damping in sandwich structures were analyzed by Zhuang Li [3]. Measurements on foam-filled honeycomb sandwich beams with different configurations and thicknesses have been performed and the results were compared with the theoretical predictions. Jones [4] published a handbook especially on viscoelastic damping. Sun et.al [5] published in recent research accomplishments on vibration damping in beams, plates, rings, and shells. Finite element models on damping treatment are also summarized in this work. There is also other good literature available on vibration damping [6]-[8]. From the above literature, it can be observed that much of the work on damping is limited to either viscoelastic or 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 PROCEDURE

A) Materials Required for Fabrication of Laminates

The constituent materials used for fabricating the epoxy/glass fiber plates are: E-Glass woven as well as E-Graphite roving 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 work were made from 0/90 woven glass fiber and graphite fiber with epoxy matrix. Specimens were fabricated by hand layup technique**.** The first layer of bi-woven glass fiber cloth (ranging from 0.25 mm to 0.35 mm) is laid and resin is spread uniformly over the cloth by means of brush. The second layer of the cloth is laid and resin is spread uniformly over the cloth by means of brush. After second layer, to enhance wetting and impregnation, a teethed steel roller is used to roll over the fabric before applying resin. Also resin is tapped and dabbed with spatula before spreading resin over fabric layer. This process is repeated till all the 10 layers (2 mm thickness) and 16 layers (4 mm thickness) are placed. No external pressure is applied while casting and curing because uncured matrix material can squeeze out under high pressure. This results in surface waviness (non-uniformed thickness) in the model material. The casting is cured at oven temperature of about 100º C up to 2 hrs & finally removed from the mould to get a fine finished composite plate as shown in the fig 1 below. Similar procedure was adopted to obtain graphite laminates.

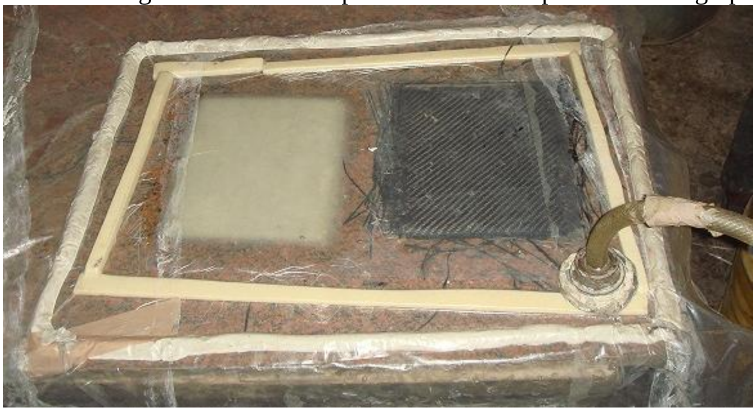

Fig – 1 Vacuum bagging Technique

C) Experimental Setup and Test Procedure for Modal Test

To simulate different boundary conditions, vibration test fixture was designed and fabricated as shown in fig 2 below. The test specimen was mounted for different test conditions such as cantilever, two sides fixed and all sides fixed. The connections of FFT analyzer, laptop, transducers, modal hammer, and cables to the system were done as per the guidance manual .The plate was excited in a selected point by means of Impact hammer. The resulting vibrations of the specimens on the selected point were measured by an accelerometer (PCB Make) mounted on the specimen by means of special wax shown in fig 3.

Fig – 2 Vibration Test Fixture

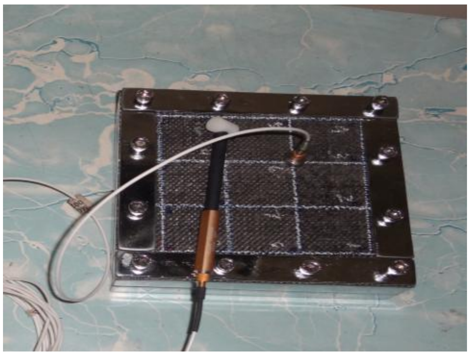

Fig – 3 Specimen fixed at all sides

III. RESULTS & DISCUSSIONS

Table – 1 Modal test results of Glass Laminates

Specimen	**Boundary Conditions**	**Frequency (Hz)**		
		Mode 1	**Mode 2**	**Mode 3**
Glass 2mm	One end fixed	45.6 (0.48%)	82.6 (1.23%)	251 (2.35%)
	Two ends fixed	404 (1.25%)	439 (1.45%)	594 (1.88%)
	All ends fixed	513 (2.17%)	971 (3.83%)	1228 (5.89%)
Glass 4 mm	One end fixed	77.8 (0.345%)	141 (0.309)	353 (0.288%)
	Two ends fixed	616 (1.91%)	721 (0.757%)	941 (1.18%)
	All ends fixed	846 (1.53%)	1660 (1.67%)	2493 (1.87%)

(Numbers in the bracket indicate the percentage modal damping)

Table – 2 Modal test results of Graphite Laminates

Specimen	**Boundary Conditions**	**Frequency (Hz)**		
		Mode 1	**Mode 2**	**Mode 3**
Graphite 2mm	One end fixed	46.1 (0.87%)	81 (1.21%)	242 (2.42%)
	Two ends fixed	394 (1.12%)	435 (1.44%)	798 (1.78%)
	All ends fixed	520 (3.24%)	1001 (1.4%)	1398 (0.98%)
Graphite 4 mm	One end fixed	74.2 (0.275%)	140 (1.13%)	448(4.19%)
	Two ends fixed	649 (1.32%)	732 (1.27%)	967 (1.10%)
	All ends fixed	877 (1.27%)	1770 (2.56%)	2091 (4.57%)

(Numbers in the bracket indicate the percentage modal damping)

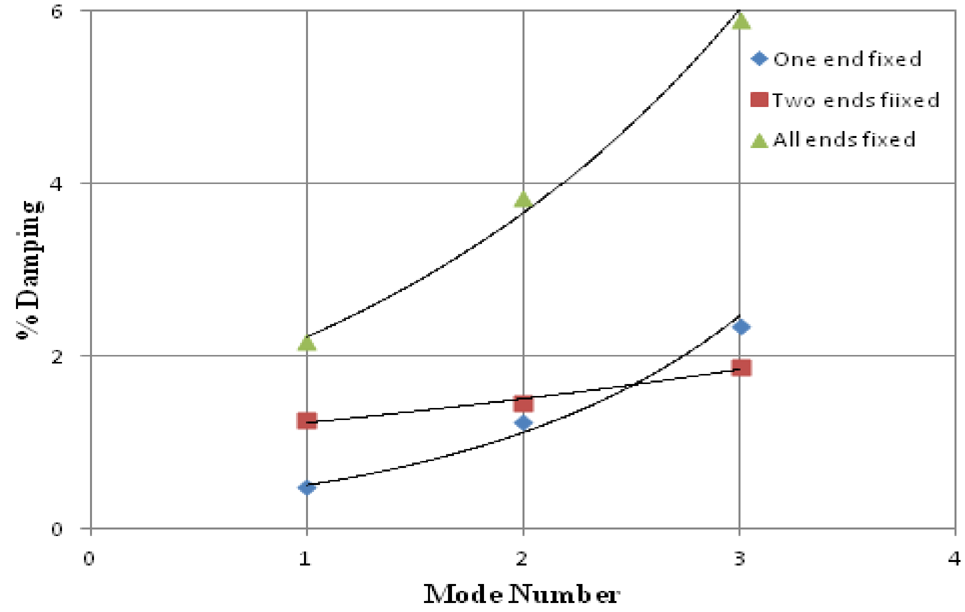

Fig – 4 Graph of Mode number Vs. Damping for Glass Laminates – 2mm

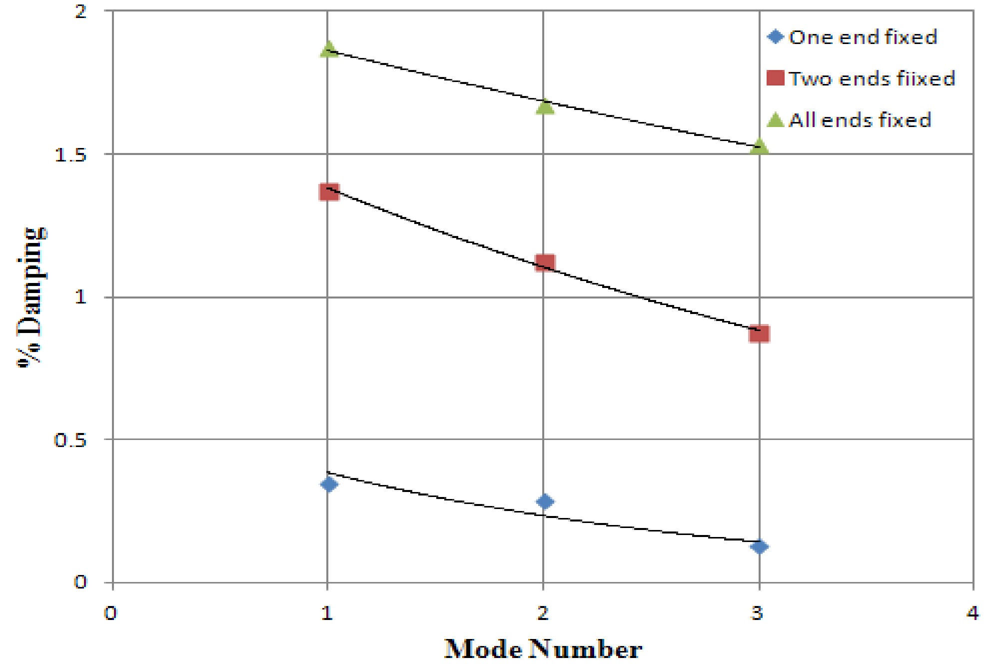

Fig –5 Graph of Mode number Vs. Damping for Glass Laminates – 4mm

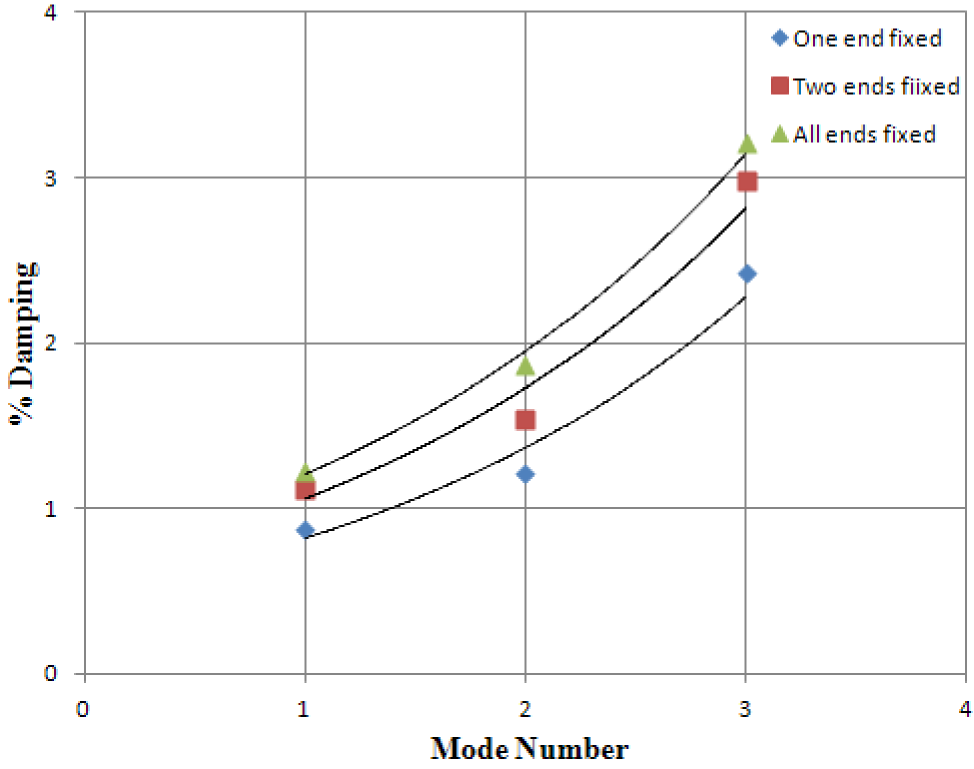

Fig – 6 Graph of Mode number Vs. Damping for Graphite Laminates – 2mm

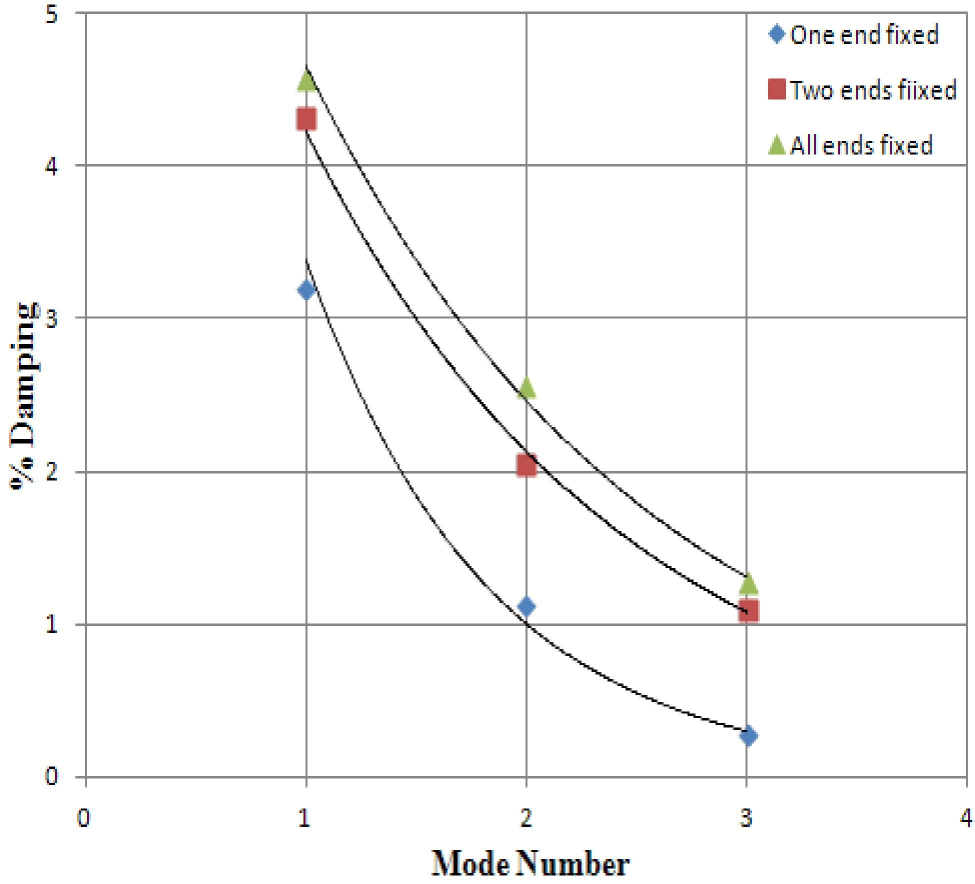

Fig – 7 Graph of Mode number Vs. Damping for Graphite Laminates – 4mm

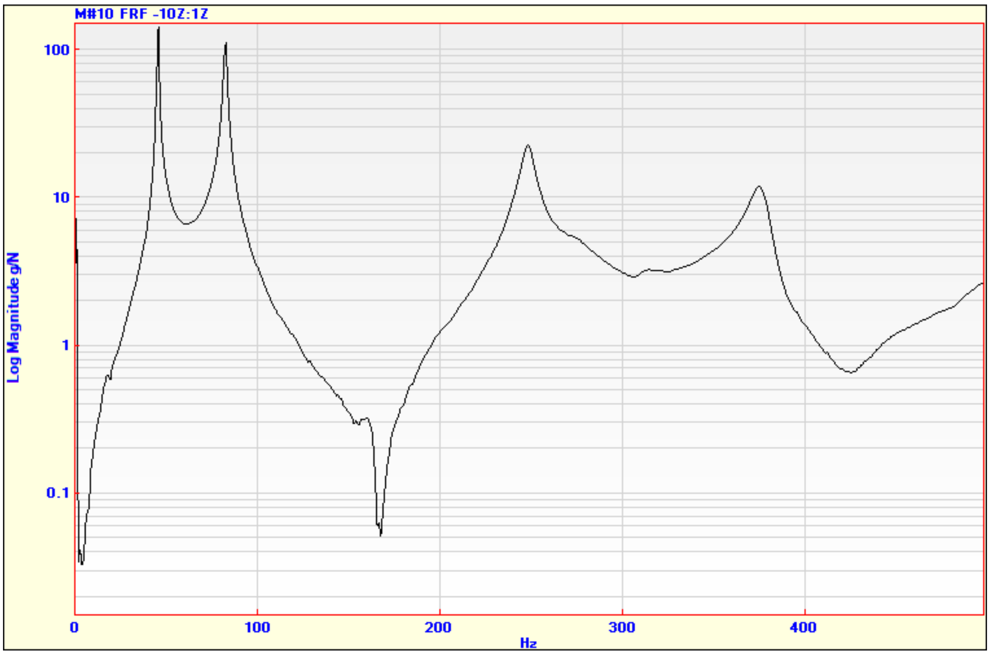

Fig – 8 Typical Frequency Response Curve for Glass laminates

Figs 4,5, 6 & 7 depicts the graphs of mode number and percentage modal damping obtained through modal testing for both glass and graphite laminates for three different boundary conditions. It can be observed that for both glass and graphite laminates of 2mm thick there seems to be increasing trend in the modal damping, whereas in case of 4mm thick laminates there is a decreasing trend. However, damping characteristics in case of graphite is more predominant as compared to glass in both low and high frequency range. Table 1 & 2 well indicates the modal damping for 2mm and 4mm thick laminates, and it is found that modal damping is weak as the laminate thickness is increased. Fig 8 indicates a typical FRF graph for glass laminates, where the peaks represent the natural frequencies at that particular boundary condition. Further, the influence of boundary conditions too plays an important role in the prediction of damping characteristics as it is evident from the figures 4, 5, 6 & 7 the damping has increased by 7.7% in case of cantilever (one end fixed) when compared to two ends fixed condition. Similar variation can be observed for the other configuration also.

IV. CONCLUSION

Damping characteristics of glass and graphite laminates under different boundary conditions with two thicknesses were evaluated through simple “strike method” test. In fact, the modal test analysis leads to the determination of the associated elastic eigenmodes and to characterize the modal damping of laminated composite panels. Therefore, adoption of modal test seems to be very simple, effective and justified. Also, the modal damping depends on geometry & mechanical properties of the laminates under test. Thus, it can be concluded that evaluation of modal damping through experimental modal technique is simple and effective.

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REFERENCES

[1] J. E. Ruzicka, Structural Damping. ASME, New Jersey (1959).

[2] B. J. Lazan, Damping of Materials and Members in Structural Mechanics. Pergamon Press, London (1968).

[3] A. D. Nashif, D. I. G. Jones, J. P. Henderson, Vibration Damping. John Wiley & Sons, Inc., New York (1985).

[4] D. I. G. Jones, Handbook of Viscoelastic Vibration Damping. John Wiley & Sons, Inc., New York (2001).

[5] C. T Sun, Y. P. Lu, Vibration Damping of Structural Elements. Prentice Hall PTR, Englewood Cliffs, NJ (1995).

[6] C. F. Beards, Structural Vibration Analysis: Modeling, Analysis, and Damping of Vibrating Structures. Halsted Press, Chichester (1983).

[7] E. E. Ungar, “Structural Damping”, Chapter 12 in Noise and Vibration Control Engineering: Principles and Applications, Leo. L. Beranek (Editor). John Wiley & Sons, Inc. (1992).

[8] D. J. Mead, Passive Vibration Control. John Wiley & Sons, New York (1999)