Variation of damping property of polymer composite under saline water treatment

Sridhar I
Department of Mechanical Engineering
S. D. M. College of Engineering & Technology
Dharwad, Karnataka, India

Venkatesha C S
Department of Mechanical Engineering
U. B. D. T. College of Engineering
Davangere, Karnataka, India

Abstract- Polymer composites are replacing the conventional materials for use in both offshore and onshore applications due to their excellent corrosion resistant and good mechanical properties. These composites are subjected to different environmental conditions during their service. The composite dynamic behavior under different environments needs to be studied for their proper functioning. Damping is an important dynamic property that needs to be evaluated for design against vibration. This study provides test results of damping behavior of glass fibre reinforced composites subjected to saline water treatment. Damping behavior was studied using free vibration decay method for different fibre volumes at regular intervals of time. The study shows that there is a decrease in damping value by a maximum of 47% of the composites.

Keywords: damping, environment, glass fibre, influence.

I.INTRODUCTION

Glass fibre reinforced polymer (GFRP) composites owing to their high specific strength and anti-corrosive property are used in many light weight and marine applications than conventional materials. These composites are subjected to severe environments and their dynamic behavior under these environments is important from the design point of view. The damping performance is an important parameter for composite structures which are subjected to dynamic loading and vibration during working. Different theoretical and experimental methods are available for determining the damping of the composites. Many researchers have successfully determined the damping behavior of unidirectional and multidirectional polymer composites [1-11].

Woven fabric polymer composites give better mechanical properties in both the directions. Energy dissipation by these composites is important when they are subjected to vibration. Many factors influence the energy dissipation of FRP composites like fiber orientation, fiber volume, matrix material, moisture, temperature and others. Research has been done to find the effect of hot and wet moisture absorption by the composites on damping properties [12, 13]. While most of the research is done on moisture or temperature effects on damping properties of composites, no data is available on the effect of long term liquid ageing on the damping properties of GFRP composites.

In the present work, the authors have carried out experiments to study the effect of liquid ageing on the damping property of GFRP composites. The composites were subjected to liquid ageing in saline water and their damping behavior is studied.

II.EXPERIMENTAL

2.1 Materials and Fabrication

The specimens were made by hand laying plain woven E-glass fabric cut to appropriate size. Commercially available Araldite epoxy LY556 and hardener HY951 mixed in appropriate proportion (10:1) were used to cast the specimens. The cast specimens were cured at room temperature for approximately 48 hours. The specimens were then cut to appropriate size. The dimensions of the specimens were 330x50x3 mm. Five different vibration specimens (VS1-VS5) were fabricated by varying the volume percentage of the glass fabric as given in Table 1.

Table-1 Damping factor and volume percentage of Glass fabric for the untreated vibration specimens

SPECIMEN	**Volume % of Glass fabric**	**Damping factor ‘ζ’** (x 10^{-3})
VS1	20	8.16
VS2	25	7.93
VS3	30	9.475
VS4	35	8.352
VS5	40	10.15

2.2 Experimental Method

The specimens prepared were soaked in saline water at room temperature. Vibration testing was done on the specimens for every 15 days of soaking and up to 60 days maximum. Before proceeding to testing, the specimens were cleaned by tissue paper so that no liquid is present on the specimen. The specimens were then subjected to vibration using impact load and the vibration decay plot was obtained. The span length of the beam specimen was 300mm. The vibration decay plot thus obtained was used for measurement of damping.

To calculate the damping factor ζ, the logarithmic decrement δ is evaluated from the vibration decay plot using equation (1) [14].

$$\delta = \frac{1}{M} \ln \frac{x_1}{x_{M+1}} \qquad (1)$$

Where x_1 and x_{M+1} are the amplitudes of vibration at 1st and Mth oscillations.

Then damping factor ζ is given by

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

For small amount of damping equation (2) can be rewritten as

$$\zeta = \frac{\delta}{2\pi} \qquad (3)$$

Equation (3) is used to calculate the damping factor of the composites. For each specimen a minimum of three readings and a maximum of six readings were taken and average damping factor was calculated.

III.RESULTS AND DISCUSSION

3.1 Damping behavior of untreated specimens

Table-1 shows the damping factor values for different untreated (dry) specimens. It can be observed that the damping increases as the volume percentage of fiber increased. This may be due to the increased stiffness of the specimen as fiber volume is increased and also due to more energy dissipation at the fiber matrix interphase which increases as the fibre volume increase.

3.2 Effect of saline water

The damping values for the specimens soaked in saline water are presented in Table 2.

Table-2. Damping factor for different specimens immersed in saline water

SPECIMEN	Damping factor 'ζ' (x 10^{-3})			
	Duration			
	15 days	**30 days**	**45 days**	**60 days**
VS1	7.424	6.088	6.467	6.048
VS2	7.846	4.805	5.554	7.00
VS3	8.724	5.037	6.367	7.96
VS4	5.125	7.321	6.80	7.106
VS5	9.086	8.73	9.330	9.858

For specimens soaked for 15days the damping decreased initially. The decrease in damping values is rather small. The decrease in the damping values ranged from 7-39%. Maximum decrease in the damping values was observed for 35% fibre volume specimen. The decrease in the damping values may be attributed to the high plasticization of the matrix material of the composite. As observed to naked eye plasticization was more in case of saline water treated specimens. Plasticization leads to reduction in stiffness of the composite and this decreases the damping of the composite.

Further reduction in the damping was observed for specimens soaked for 30 days. In this case, may be the water uptake was not much by the composite and further plasticization of the composite lead to the reduction in the damping values of the composite. Also this shows that the water has not reached the fibre-matrix interphase so as to cause degradation which acts as an additional site for energy dissipation. The decrease in the damping values is from a minimum of 12% to a maximum of 47%. Maximum decrease was observed for 30% fibre volume specimen. These specimens show great reduction in damping than any other specimens. This can be observed in figure 1.

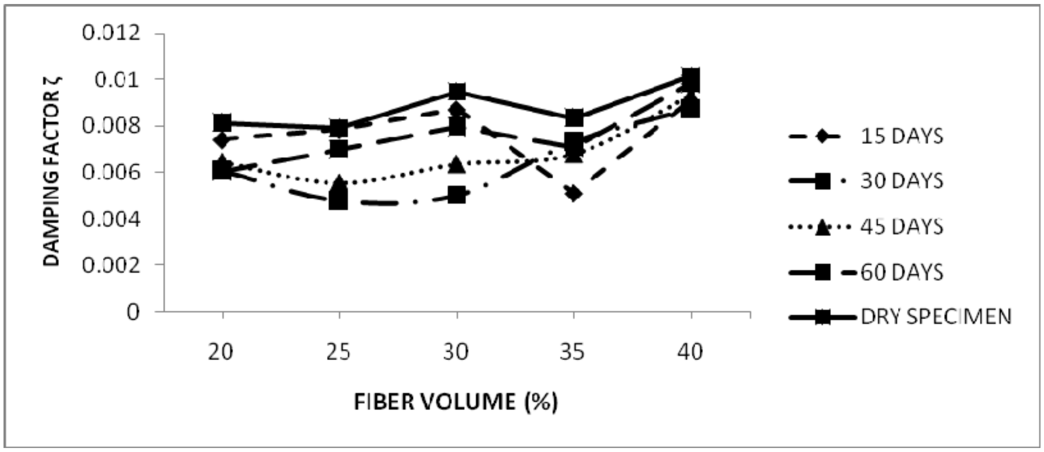

Figure 1. Variation of damping factor with fibre volume for treated and untreated specimens.

For specimens exposed for 45 days time interval the damping values reduced continuing the same trend as before. But the damping increased as compared to 30 days treated specimens. The decrease in the damping values is from 8-33%. Maximum decrease was shown by 30% fibre volume specimen. As the water uptake increases, it reaches the fibre-matrix interphase. These water molecules start degrading the interphase region. Water uptake may cause swelling in the composites. This results in uneven expansion of the matrix and fibre providing additional sites for energy dissipation. These factors tend to increase the energy dissipation capacity of the composite. Hence there is slight increase in the damping capacity of the composite as compared to 30 days treated specimens. Also the mass of the composite increases due to uptake of the water and adds to increase in damping capacity of the composite.

Specimens immersed for 60 days time period show reduction in damping than untreated specimens. An increase in the damping values is observed compared to 45 days treated specimens. This is obvious of the fact that, as saturation is reached for water uptake more energy is dissipated from the composite through different mechanisms. Also as indicated in the above section the mass of the composite increases till saturation. All these factors lead to increase in the damping values of the composite. The chemical reaction occurring between the composite and the saline water causes leaching and hydrolysis. And to some extent this also enhances the damping capacity of the composite. The reaction will degrade the composite and additional sites are available for energy dissipation. The reduction in damping values varied from a minimum of 11% to a maximum of around 29%. Maximum decrease in the damping was observed for 40% fibre volume specimen.

IV.CONCLUSIONS

Free vibration analysis was carried out to find the variation of damping of GFRP composites of varying fiber volume subjected to saline water ageing. Damping factor was calculated for all the specimens at regular intervals of time using the logarithmic decrement method. From the study made, it is found that specimens' exhibit initial decrease in damping up to a maximum of 47% for specimens soaked for 30 days and increase for further soaking time but well below the untreated specimens. Thus, damping of the composite depends on fiber volume and the duration of liquid ageing.

REFERENCES

[1] Berthelot, J.M., and Sefrani, Y. "Longitudinal and transverse damping of unidirectional fiber composites", *composite structures*, **79**(3): 423-431, 2007.

[2] Ni, R.G., and Adams, R.D. "A rational method for obtaining the dynamic mechanical properties of laminate for predicting the stiffness and damping of laminated plates and beams", *composites*, **15**(3): 193-199, 1984.

[3] Crane, M., and Gillespie, W. J. "Characterization of the vibration damping loss factor of glass and graphite fiber composites", *composites science and technology,* **40**(4): 355-375, 1991.

[4] Botelho, E. C., Campos, A. N., DeBarros, E., Pardini, L.C., and Rezends, M.C. "Damping behavior of continuous fiber/metal composite materials by the free vibration method", *composites part B: Engineering,* **37**(2-3): 255-263, 2006.

[5] Chandra, R., Singh, S. P., and Gupta, K. "Experimental evaluation of damping of fiber-reinforced composites", *Journal of composites, technology and research,* **25**(2): 1-12, 2003.

[6] Naghipour, M., Taheri, F., and Zou, G. P. "Evaluation of vibration damping of glass-reinforced polymer-reinforced glulam composite beams", *Journal of structural engineering,* **131**: 1044-1050, 2005.

[7] Wei, C. Y., and Kukureka, S. N. "Evaluation of damping and elastic properties of composites and composite structures by resonance technique", *Journal of materials science,* **35**: 3785-3792, 2000.

[8] Berthelot, J. M., and Sefrani, y. "Damping analysis of unidirectional glass and Kevlar fibre composites", C*omposites science and technology,* **64(**9): 1261-1278, 2004.

[9] Sun, c. T., Wu, J. K., and Gibson, R. F. "Prediction of material damping of laminated polymer matrix composites", *Journal of materials science,* **22**: 1066-1012, 1987.

[10] Hadi, A. S., and Ashton, J. N. "Measurement and theoretical modeling of the damping properties of a unidirectional glass/epoxy composite", *composite structures,* **34**(4) 381-385, 1996.

[11] Vantomme, J. "A parametric study of material damping in fibre-reinforced plastics", *composites,* **26**(2): 147-153, 1995.

[12] Djumaev, D., and Takahashi, K. "Effect of moisture absorption on damping performance and dynamic stiffness of NY-6/CF commingled yarn composites", *Journal of materials science,* **29**: 4736-4741, 1994.

[13] Adams, R. D., and Singh, M. M. "The dynamic properties of fiber reinforced polymers exposed to hot, wet conditions", *composites science and technology,* **56**(8): 977-997, 1996.

[14] Rao, S.S *Mechanical Vibrations,* 4th ed. pp.147-149, 2004, Pearson Education publishers, India.