Influence of Liquid Environments on the Damping Property of Polymer Composites

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Abstract

Polymer composites are widely used in aerospace and marine applications due to their excellent corrosion resistant and good mechanical properties. These composites are subjected to different environmental conditions during service and their dynamic behavior under these environments needs to be studied for proper functioning and design. Damping is one such critical parameter that needs to be studied for assessing the vibrational behavior of the composites subjected to varied environments due to impact loading. This study provides test results of damping behavior of glass fiber reinforced polymer composites subjected to three different liquid environments, sea water, normal water and saline water. Damping behavior was studied by varying the fibre volume using free vibration decay method at regular intervals of time. The study shows that damping of the composite is dependent on the environment it is subjected to. For specimens subjected to sea water, the damping increased for initial period of ageing by maximum 36% and decreases further. The normal water and saline water treated specimens exhibit decrease in damping behavior for initial period of ageing by maximum 47% and increases further. The variation of damping of treated specimens with untreated specimens is also presented.

Keywords— Damping, Environment, GFRP composite, influence.

1. Introduction

Glass-fiber reinforced polymer (GFRP) composites owing to their high specific strength and anti-corrosive property are used in many light weight and offshore 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. A good amount of literature is available on analytical and experimental methods to determine damping properties of fiber reinforced polymer composites [1-11].

Woven fabric polymer composites give better mechanical properties in both the directions than random or unidirectional composites. The dynamic properties of these composites vary with the environmental conditions in which they have been put to use. 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 moisture absorption by the composites on damping properties [12, 13]. It has been found that damping increases with moisture saturation at the same temperature [14]. While most of the research is done on hygrothermal effects on damping properties of composites, no data is available on the effect of different environments on the damping properties of GFRP composites and for longer durations of time.

In the present work, the authors have carried out experiments to study the effect of different liquid environments on the damping property of GFRP composites. The composites were subjected to three different environments; sea water, saline water, and normal water at room temperature and their damping behavior is studied.

2. Experimental

a. Materials and Fabrication

The specimens were made by hand layup procedure using plain woven E-glass fabric cut to appropriate size. Araldite epoxy LY556 and hardener HY951 mixed in appropriate proportion were used to cast the specimens. The cast specimens were cured at room temperature for approximately 48 hours. The dimensions of the specimens cut are 330x50x3mm.

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

b. Experimental setup and Method

The specimens prepared were soaked in natural sea water, saline water and normal water at room temperature. Vibration testing was done on the specimens for every 15 days of soaking and up to a maximum of 60 days. Before proceeding to testing, the specimens were cleaned by tissue paper so that no liquid is present on the specimen. The span length of the beam specimen was 300mm. An impact load was applied to the specimen to induce vibration using a spherical ball hammer. The location of impact was 200mm from the free end of the specimen. The vibration decay plot obtained was then 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) [15].

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

Where x_1 and x_{m+1} are the amplitudes of vibration at 1^{st} and m^{th} oscillations.

Then damping factor ζ is given by

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

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

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

Equation (3) was 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.

3. Results & Discussion

a. Damping behavior of untreated specimens

Table 1. shows the damping factor values for different untreated dry specimens. It can be seen

that the damping increases as the volume percentage of fiber is increased. This is may be due to increased stiffness of the specimen as fiber volume is increased and also due to more energy dissipation at the fiber matrix interphase as the fiber matrix interphase area increases with fiber volume.

b. Effect of sea water

The damping values obtained for specimens immersed in sea water is given in table 2.

TABLE 2.

Damping factor for different specimens immersed in sea water.

SPECIMEN	Damping factor 'ζ' (x 10^{-3})			
	Duration			
	15 days	30 days	45 days	60 days
VS1	8.912	11.13	8.565	8.301
VS2	9.10	10.07	8.868	8.705
VS3	6.614	11.16	9.842	8.602
VS4	8.251	10.176	9.134	8.234
VS5	9.55	12.37	10.68	12.65

It can be seen that the damping increases as the duration of soaking is increased up to 30 days and decreases for further soaking time. A maximum amount of 36% increase in damping can be found for VS1 specimen. The increase in damping initially can be attributed to the increase in mass of the specimen due to the absorption of sea water. The water molecules can react with the matrix material and to some extent the glass fibres. The water uptake by the composite causes swelling and causes stress to be induced in the composite. This uneven expansion of the composite provides additional sites for energy dissipation. As saturation is reached, the absorption decreases and degradation of the composite begins. Degradation of composites may result from hydrolysis, plasticization, saponification, leaching and other mechanisms. This can result in decrease in damping which can be seen from the values obtained. The damping value of VS3 specimen for 15 days is low compared to others. This may be due to increased plasticization of the composite resulting in reduced stiffness. The damping of all the specimens is almost constant at the end of 60 days except VS5. The increase in damping of VS5 may be due to the void content variation.

c. Effect of Normal water

Table 3. gives the damping values for the specimens soaked in normal water. The damping initially decreases up to 15 days of soaking time and then increases as the soaking time is increased. A maximum of 31% decrease in damping can be seen for VS4 specimen. All the values here also are well below the dry untreated specimens except VS2 (30 days and 60 days) specimen. This reduction in damping may be due to the high plasticization of the composite due to normal water. Normal water does not contain any salt and other ingredients which can react with the matrix and fibres of the composite. Only water molecules are available for the diffusion process. As the water molecules diffuse into the matrix plasticization is the immediate effect. This may be prominent here than seawater treated specimens

TABLE 3

Damping factor for different specimens immersed in normal water.

SPECIMEN	Damping factor 'ζ' (x 10^{-3})			
	Duration			
	15 days	30 days	45 days	60 days
VS1	6.79	7.302	6.188	7.44
VS2	6.366	8.341	6.893	8.623
VS3	6.634	6.846	7.154	6.674
VS4	5.752	7.712	5.781	8.044
VS5	8.363	8.806	7.852	8.77

d. Effect of saline water

The damping values for the specimens soaked in saline water are presented in Table 4. It can be seen that damping values initially decrease up to 30 days of soaking time and then increase as the soaking time increased. A maximum amount of 47% decrease in damping can be seen for VS3 specimen. An important observation made here is the damping values obtained here for all the specimens and for all days is less than the values obtained for dry untreated specimens. The decrease in the damping values may be attributed to the high plasticization of the matrix material of the composite. Even though saline water contains salt molecules, the behavior of the composite is quite different from seawater treated specimens which showed increase in the damping values. This shows the dependency of damping property on the composition of the immersion medium. Seawater and saline water both contain salt molecules. But natural seawater contains different other minerals than saline water. Perhaps these other minerals interaction with the composite played a major role in the damping behavior of the composite in case of seawater treated specimens

TABLE 4

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

e. Comparison between sea water, saline water and normal water specimens

Figures 1-4 shows the damping behavior of the specimens in different mediums for different soaking times. It can be observed that sea water soaked specimens present almost highest damping values than other specimens.

Saline water soaked specimens has good damping initially and later the damping decreases and present to be the least of all the treated specimens.

Normal water specimens exhibit initial decrease in damping and later damping increases, but well below the sea water soaked specimens. Important observations made here are:

- For specimens subjected to sea water, the damping initially increases up to 36% and later decreases.
- For specimens subjected to saline and normal water, the damping decreases up to 47% and 31% respectively initially and increases for further soaking time but well below the untreated specimens.

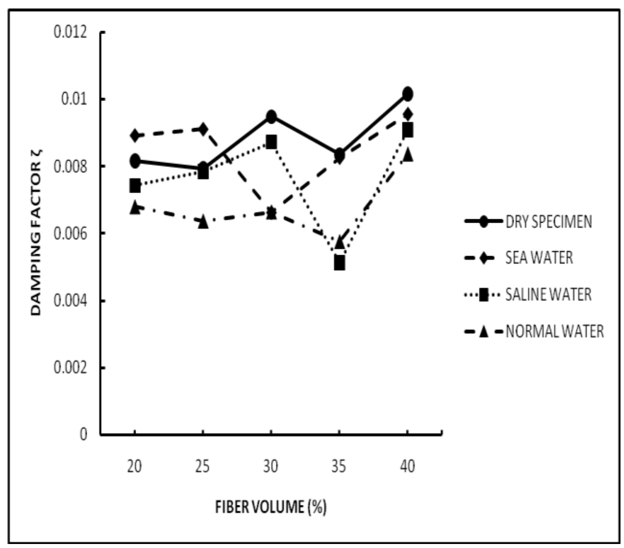

Fig. 1 Variation of damping for different specimens immersed for 15 days.

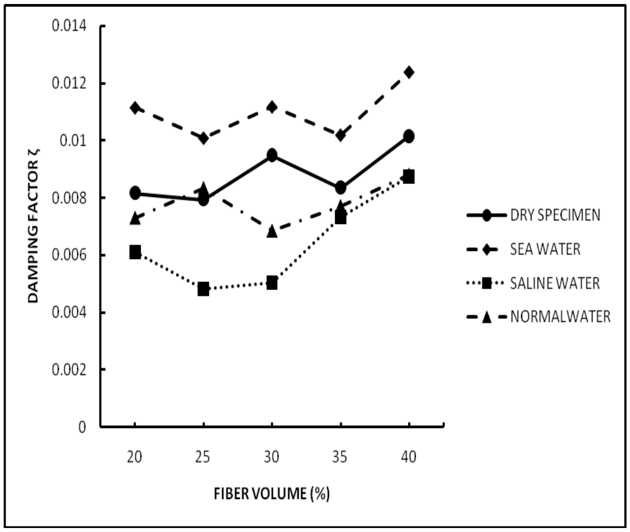

Fig. 2 Variation of damping for different specimens immersed for 30 days.

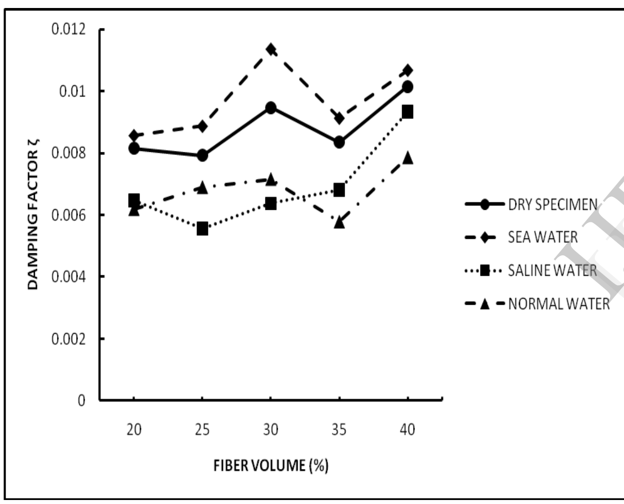

Fig. 3 Variation of damping for different specimens immersed for 45 days.

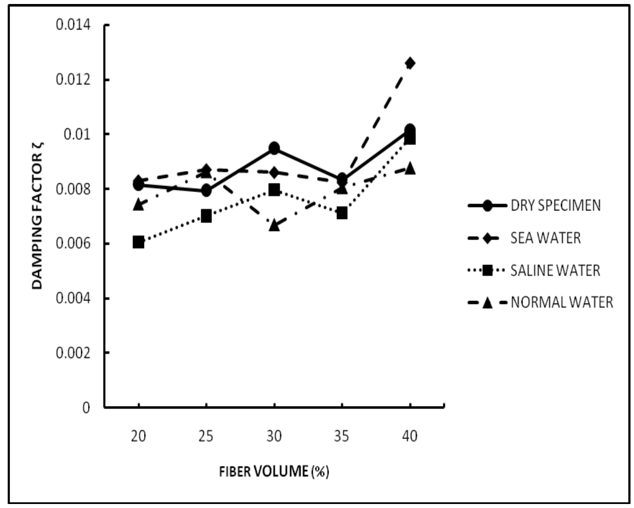

Fig. 4 Variation of damping for different specimens immersed for 60 days.

f. CONCLUSION

Vibration analysis was carried out to find the variation of damping of GFRP composites by varying fiber volume subjected to different liquid environments. Three different liquids were used for soaking and the damping factor was calculated for all the specimens at regular intervals of time using the decay method. From the study made, it is found that sea water soaked specimens exhibit good damping compared to normal and saline water soaked specimens. Thus it is evident that damping is dependent on the environment to which a composite is subjected to apart from other factors. Further results show that for sea water soaked specimens, the damping increased initially by a maximum amount of 36% and later decreased. For other specimens, damping initially decreased by a maximum amount of 47% in case of saline water and later increased. Thus, damping of the composite depends on fiber volume, environment to which it is subjected to and the duration of treatment.

REFERENCES

[1] Berthelot, J.M., and Sefrani, Y. “Longitudinal and transverse damping of unidirectional fiber

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composites" *composite structures,* vol.79 (3), 2007, pp. 423-431.

[2] Ni, R.G., and Adams, R.D."A rational method for obtaining the dynamic mechanical properties of laminae for predicting the stiffness and damping of laminated plates and beams", *composites*, vol. 15(3), 1987, pp. 193-199.

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

[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,* vol. 37(2-3), 2006, pp. 255-263.

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

[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,* vol. 131, 2005, pp. 1044-1050.

[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,* vol. 35, 2000, pp. 3785-3792.

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

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

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

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

[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,* vol. 29, 1994, pp. 4736-4741.

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

[14] Pulter, S., Buchanan, D. L., and Rehfield, L. W." Influence of frequency and environmental conditions on dynamic behavior of graphite/epoxy composites", In: Daniel, I. M., Editor, Composite materials: testing and design; 1981: 12-13 May, Phoenix, Arizona: ASTM: 1982. p. 414-424.

[15] S.S. Rao, *Mechanical Vibrations,* pearson education, India, 2004, pp. 147-149.