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The Influence of the Different Fiber lay-ups on the Damping Characteristics of Polymer Matrix Composite

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Abstract: The dynamic characteristics of glass fiber reinforced polymer composites have been studied for the large number of different lay-ups of fiber, intending to get a better damping without compromising much on the stiffness/frequency values. The better layup has been selected based on the damping and frequency values in mode shapes 1, 2 and 3 and the different layups have then been categorized into three groups (A, B and C). The experimental test was carried out to calculate the natural frequencies and damping factors using Impulse technique (Lab view software-National instruments). The same values have also been evaluated theoretically by the modal analysis performed in FEM software (ANSYS version 11). A good agreement exists between the experimental and theoretical values.

Key words: Vibration, damping factor, impulse technique, modal analysis, finite element analysis

INTRODUCTION

In recent years, the crucial applications like aerospace and automotive industries prefer the light weight polymer composite materials over the weighty metallic structures where the considerable strength and stiffness is required at the normal temperature (Adams and Maheri, 2003), as the farmer possess the key properties like light weight, high specific strength, impact resistance, thermal stability etc., required for those applications (Zhang and Chen, 2006). It also offers the other benefits like high energy dissipation, flexible bonding of fiber with the matrix, less stress concentration, corrosion resistance, etc. (Rao *et al*., 1997). As the damping is considered to be a major concern in many engineering fields, this work is confined to the method of energy dissipation (damping) only. The recent researches carried out to improve the damping by the several ways of various damping mechanisms such as the viscoelastic behavior of polymer matrix, the different fiber orientations, the hair line cracks, inter faces, flexible bonding of fiber with the matrix and temperatures which help the composite structure to dissipate the absorbed energy (Zhang and Chen, 2006; Rao *et al*., 1997). Though, the Fiber Reinforced Polymer (FRP) composite material provides higher damping it can be achieved only at the expense of strength and stiffness. So, the research is still incomplete in improving the damping without compromising the stiffness of FRP composites.

Adams and Bacon (1973) theoretically predicted the effect of fiber orientation and laminate geometry on the flexural, torsional damping and modulus of fiber reinforced composites. Later, to study the effect of the same fiber orientation and moduli, Adams and Maheri (1994) used the basic plane stress relations together with Adams-Bacon damping criterion (Adams and Bacon, 1973). Gibson and Plunkett (1976) represented analytical and experimental methods to find the internal damping and elastic stiffness of E-glass fiber reinforced elastic beams under flexural vibrations.

The effect of temperature on the modal parameters (resonance frequencies and modal loss factors) of multi-damping layer anisotropic laminated composite beam was predicted by the modal strain energy method using FEM as a tool by Rao *et al*. (1997). Then Berthelot and Sefrani (2007), Sefrania and Berthelot (2006) and Berthelot (2006) also studied the damping behavior under the influence of temperatures, apart from studying the effect of beam width. Rao *et al.* (1997) and Zhang and Chen (2006) studied the damping behavior of composites with integral viscoelastic layers under the effect of ply angle of complaint layers and the location of viscoelastic layers.

The objective of this study is to improve the damping without compromising much on the stiffness/frequency

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values by suitable layups. To achieve this, the damping factors and frequency were experimentally determined from the different range of fiber lay-ups. Similarly the values obtained from the experimental work have also been compared with the same obtained from the FEA modal analysis.

MATERIALS AND METHODS

Materials: The low temperature curing epoxy resin, Rotex EP- 207S with a specific gravity of 1.14 at 25°C, the solvent based high temperature curing hardener, Rotex EH- 210S and the accelerator, Tertiary amine which were supplied by ROTO Polymers, Chennai, India, were used as the matrix and the unidirectional glass fiber supplied by SUNTECH Fibers, Chennai, India was taken as reinforcement in the composite.

Fabrication of FRP composites: The conventional hand layup technique, described elsewhere Yuhazri *et al.* (2010) was used to prepare the three identical test specimens with the dimension of 300×25 mm of the composite laminates, which were fabricated by stacking eight layers and also by applying the mold pressure. The test specimen has different stacking sequence such as unidirectional and angle plies with 50% volume fraction of fiber in the composite. The different orientations of 21 layups have been given below:

Sample No.	Lay ups
Lay- up No: 1	$[60^\circ]_8$
Lay- up No: 2	$[\pm 60^\circ]_{2s}$
Lay- up No: 3	$[90^\circ]_8$
Lay- up No: 4	$[\pm 60^\circ/\pm 45^\circ]_s$
Lay- up No: 5	$[\pm 60^\circ/45^\circ/30^\circ]_s$
Lay- up No: 6	$[\pm 60^\circ/45^\circ/-30^\circ]_s$
Lay- up No: 7	$[\pm 60^\circ/90^\circ/0^\circ]_s$
Lay- up No: 8	$[90^\circ/60^\circ/45^\circ/30^\circ]_s$
Lay- up No: 9	$[45^\circ]_8$
Lay- up No: 10	$[\pm 60^\circ/\pm 30^\circ]_s$
Lay- up No: 11	$[\pm 45^\circ]_{2s}$
Lay- up No: 12	$[\pm 45/\pm 30^\circ]_s$
Lay- up No: 13	$[\pm 45^\circ/90^\circ/0^\circ]_s$
Lay- up No: 14	$[\pm 45^\circ/30^\circ/0^\circ]_s$
Lay- up No: 15	$[90^\circ/0^\circ/\pm 60^\circ]_s$
Lay- up No: 16	$[90^\circ/0^\circ]_{2s}$
Lay- up No: 17	$[90^\circ/0^\circ/\pm 45^\circ]_s$
Lay- up No: 18	$[90^\circ/0^\circ/\pm 30^\circ]_s$
Lay- up No: 19	$[\pm 30^\circ]_{2s}$
Lay- up No: 20	$[\pm 30^\circ/90^\circ/0^\circ]_s$
Lay- up No: 21	$[0^\circ]_8$

Damping test of FRP composites: The impulse technique was used to find the vibration characteristics of the specimen in terms of natural frequencies and damping factors. The procedure of this technique is described elsewhere (Kishi *et al.*, 2004). The one end of laminated specimen was rigidly clamped in a rigid support by screws and another end was free on which the accelerometer was properly positioned, to vibrate like a cantilever beam. The loss or damping factor of the composites was measured by mechanical impedance in which the specimen was forced to vibrate at its end, as shown in Fig. 1. The input load was used given by the instrumented impacts hammer and the output (response) was taken by the accelerometer and read by the national instrument data acquisition card used for vibration analysis.

The damping factor (η) is obtained by using the half power bandwidth method as shown in Fig. 2 and the expression for damping factor (η) is given by the following Eq. 1:

$$\eta = \frac{f_1 - f_2}{2f_n} \tag{1}$$

where, f_1 and f_2 is Band width at the half-power points of resonant peak for n^{th} mode and f_n is Natural frequency.

Damping factor and natural frequency of composite specimens with different fiber orientations and layup corresponding to the first mode were computed.

Mechanical test of FRP composites: The material properties of the composite specimen with respect to fiber direction were measured from the mechanical and dynamic tests and. To measure the Poisson ratio, the specimen on which two unidirectional strain gages with 120 Ω resistance both in vertical and horizontal directions were pasted at its centre was held and stretched in UTM (Manufacture: Blue hill, Model: UTE 40T), then the Damping factor and natural frequency of composite specimens with different fiber orientations and layup corresponding to the first mode were computed. required data were captured by a data acquisition (FIE through an extensometer) system using a software, named system 5000.

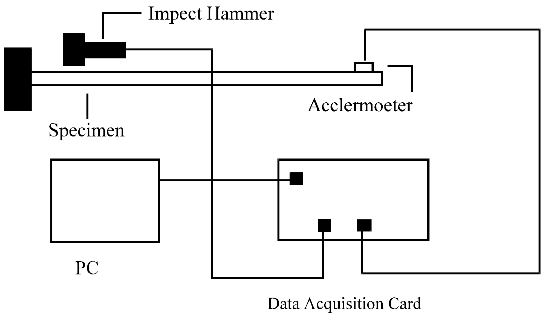

Fig. 1: Schematic representation of experimental setup

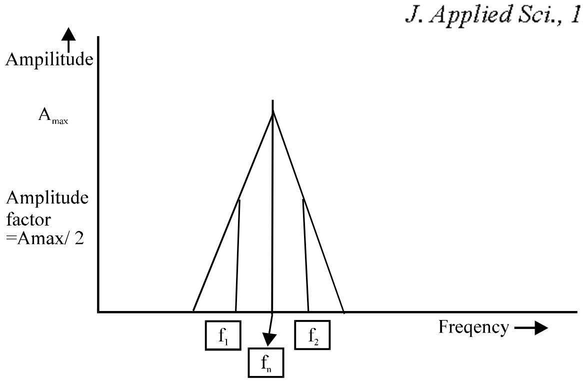

Fig. 2: Showing the Half power bandwidth method

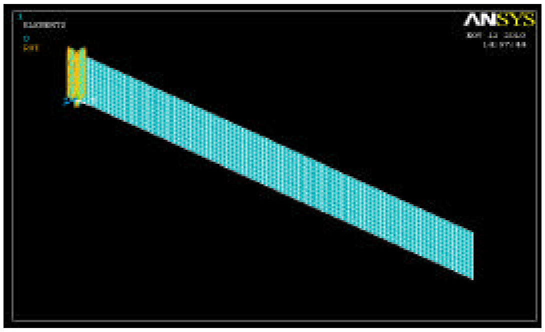

Fig. 3: Modeling of FRP composite

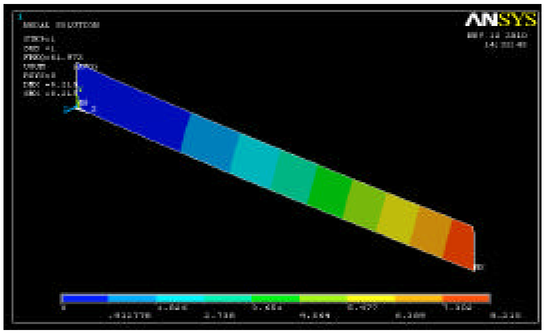

Fig. 4: Mode shape of FRP composite

Finite element analysis: The SHELL 99 (Fig. 3) 3-D shell element is used to model the structures. It allows a total of 250 uniform-thickness layers with a side-to-thickness ratio of roughly 10 or greater. The natural frequencies are determined for each individual element using the experimentally obtained modulus values (E_x, E_y, G_{xy}), poison ratio (ν_{xy}), density (ρ) and experimentally predicted damping values after discretizing the model into fine elements. So, the higher natural frequencies were accurately. Sefrania and Borthelot (2006) predicted by refining the mesh with more and more no of fine elements and admitting more number of degree of freedom. The dimension of composite material shown in Fig. 3 is 0.3×0.025×0.0066 m. The numerical values were obtained for the natural frequencies and Fig. 4 show the model shape of the composite laminate which were arranged in different sacking sequence such as unidirectional and angel plies.

RESULTS AND DISCUSSION

As the main aim of this study is to improve the damping at the negligible expense of stiffness, the damping factors and the frequencies are calculated from the lay-ups of fibers. More than 20 layups were tested and such huge numbers of the same have been tried first time. The layups have been categorized into the three groups (group A, group B and group C) consisting of different lay-ups based on the ascending order of frequency values and the descending order of the damping values arranged. Based on their magnitude, the best group and the lay-up number are selected.

It is desired to select higher damping value without compromising much on frequency values which directly relate to stiffness from the groups described above. Though the values calculated are for the three mode shapes, the first mode shape values are given the preference for the selection of best lay-up as the failure mostly initiate in the first mode only. From the twenty one layups it is observed that the laminates with orientations $[90°/0°/\pm60°]_s$, $[90°/0°]_{2s}$, [90°/0°/±45°] and [90°/0°/±30°]s of group C (shown in Table 3) exhibit the better results. When the properties of the layup $[90°/0°/\pm60°]_s$ is compared with the other layups $[90°/0°]_{2s}$,$[90°/0°/\pm45°/]_s$ and [90°/0°/±30°]s, the former is considered to be better as their damping value in the mode shape 1 is comparatively high (0084) with negligible expense of frequency (87.387 Hz).

Thus, after considering the frequency and damping values, the best one has been chosen from these entire layups. But this paper does not end with only the selection of one layup. Based on the end applications which depend upon the required parameter of either the frequency (stiffness) alone or the damping alone or combination of the both, the each group could be chosen separately. When here is a light duty application with the need of more damping, the group A (Table 1) strength/stiffness/frequency with less of damping, the group C (Table 3) can be desired. On the other hand, an application where medium duty application is in need of both parameters (frequency and damping), the group B (Table 2) may be opted.

Table 1: Group A: Materials showing low stiffness (frequency) and high damping values

		Frequency values	Damping values
Lay up No.	Lay ups	Mode Shape 1	Mode Shape 1
1	$[60^\circ]_8$	57.378	0.0122
2	$[\pm 60^\circ]_{2s}$	57.614	0.0120
3	$[90^\circ]_8$	58.068	0.0129
4	$[\pm 60^\circ/\pm 45^\circ]_s$	59.368	0.01142
5	$[\pm 60^\circ/45^\circ/30^\circ]_s$	59.846	0.01131
6	$[\pm 60^\circ/45^\circ/-30^\circ]_s$	60.002	0.01124
7	$[\pm 60^\circ/90^\circ/0^\circ]_s$	60.352	0.0112
8	$[90^\circ/60^\circ/45^\circ/30^\circ]_s$	61.113	0.0111
9	$[45^\circ]_8$	61.972	0.0109
10	$[\pm 60^\circ/\pm 30^\circ]_s$	63.927	0.0102

Table 2: Group B: Materials showing moderate stiffness and high damping values

		Frequency values	Damping values
Lay up No.	Lay ups	Mode 1	Mode 1
11	$[\pm 45^\circ]_{2s}$	66.481	0.0096
12	$[\pm 45^\circ/\pm 30^\circ]_s$	70.228	0.0088
13	$[\pm 45^\circ/90^\circ/0^\circ]_s$	70.284	0.0087
14	$[\pm 45^\circ/30^\circ/0^\circ]_s$	71.067	0.00862

Table 3: Group C: Materials showing high stiffness and high-low damping values

		Frequency value	Damping values
Lay up No.	Lay ups	Mode 1	Mode 1
15	$[90^\circ/0^\circ/\pm 60^\circ]_s$	87.387	0.0084
16	$[90^\circ/0^\circ]_{2s}$	88.368	0.00835
17	$[90^\circ/0^\circ/\pm 45^\circ]_s$	88.898	0.0083
18	$[90^\circ/0^\circ/\pm 30^\circ]_s$	91.795	0.0079
19	$[\pm 30^\circ]_{2s}$	91.999	0.00788
20	$[\pm 30^\circ/90^\circ/0^\circ]_s$	93.515	0.00752
21	$[0^\circ]_8$	131.66	0.0046

CONCLUSION

In order to study the vibration characteristics of glass fiber reinforced polymer composites, aiming to improve the damping without compromising much on the stiffness/frequency values, the large number of different lay-ups of fiber were fabricated. After carrying out a thorough investigation on damping characteristics of different lay-ups experimentally and analytically, the lay-up $[90^\circ/0^\circ/\pm 60^\circ]_s$ was selected to be good as the amount of the damping values are reasonably high with their corresponding frequency (stiffness) values. And also, on concerning the suitable lay-up for the required type of applications (light, medium and heavy duty), these different layups were categorized into three groups by the level of the stiffness(frequency) values after arranging them in ascending order.

REFERENCES

Adams, R.D. and D.G.C. Bacon, 1973. Effect of fibre orientation and laminate geometry on the dynamic properties of CFRP. J. Compos. Mater., 7: 402-428.

Adams, R.D. and M.R. Maheri, 1994. Dynamic flexural properties of Anisotropic fibrous composite beams. Compos. Sci. Technol., 50: 497-514.

Adams, R.D. and M.R. Maheri, 2003. Damping in advanced polymer-matrix composites. J. Alloys Comp., 355: 126-130.

Berthelot, J.M. and Y. Sefrani, 2007. Longitudinal and transverse damping of unidirectional fibre composites. Compo. Struct., 79: 423-431.

Berthelot, J.M., 2006. Damping analysis of laminated beams and plates using the Ritz method. Compo. Struct., 74: 186-201.

Gibson, R.F. and R. Plunkett, 1976. Dynamic mechanical behavior of fiber-reinforced composites measurement and analysis. J. Compos. Mater., 10: 325-341.

Kishi, H., M. Kuwata, S. Matsuda, T. Asami and A. Murakami, 2004. Damping properties of thermoplastic-elastomer interleaved carbon fiber-reinforced epoxy composites. Compos. Sci. Technol., 64: 2517-2523.

Rao, M.D., R. Echempati and S. Nadella, 1997. Dynamic analysis and damping of composite structures embedded with viscoelastic layers. Compos. Part B, 28: 547-554.

Sefrani, Y. and J.M. Berthelot, 2006. Temperature effect on the damping properties of unidirectional glass fibre composites. Compo. Part B: Eng., 37: 346-355.

Yuhazri, M., Y.P.T. Phongsakorn and H. Sihombing, 2010. A comparison process between vacuum infusion and hand layup method toward Kenaf/ Polyester composites. Int. J. Basic Applied Sci. IJBAS-IJENS, 10: 63-66.

Zhang, S.H. and H.L. Chen, 2006. A study on the damping characteristics of laminated composites with integral viscoelastic layers. Compos. Structures, 74: 63-69.