Research Article
Vibrational Analysis and Mechanical Properties of Epoxy Composite Material for Automobile Leaf Spring

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Abstract: The composites have found extensive application in various fields. The aim of this work is to analyze the mechanical properties and damping effect of the laminates of the composites. The vibration in the composite material that to be used in the application of automobiles for the purpose of leaf spring has to be reduced. So the damping capacity of the composites was found out. Also the tensile and impact properties were studied using existing ASTM standard testing procedures and the results are reported. Based on the experimental study, it is observed that the tensile and impact strength are similar to that of steel. After studying the tensile strength, impact strength, damping capacity and water absorption of the composite, it is useful in suggesting the different types of composites, may be hybrid or may be with uni-directional fiber or with some other fibers, so that the required mechanical properties is achieved.

Keywords: Damping capacity, impact, mechanical properties, reinforced composites, tensile, water absorption

INTRODUCTION

Fiber-reinforced composite materials consist of fibers of high strength and modulus embedded in or bonded to a matrix. In this form, both fibers and matrix retain their physical and chemical identities, yet they produce a combination of properties that cannot be achieved with either of the constituents acting alone .The most common form in which fiber-reinforced composites are used in structural applications is called a laminate, which is made by stacking a number of thin layers of fibers and matrix and consolidating them into the desired thickness.

Many fiber reinforced polymers offer a combination of strength and modulus that are bar with or better than many traditional metallic materials. Because of their low density, the strength weight ratios and modulus-weight ratios of these composite materials are marked superior to those of metallic materials

The laminates of fiber-reinforced composites are used in structural applications, which are made by stacking a number of thin layers of fibers and matrix and consolidating them into the desired thickness.

Another unique characteristic of many fiber-reinforced composites is their high internal damping. This leads to better vibration energy absorption within the material and results in reduced transmission of noise and vibrations to neighbouring structures (Ewins, 1984). High damping capacity of composite materials can be beneficial in many automotive applications in which Noise, Vibration and Harshness (NVH) are critical issues for passenger comfort (Allemang and Brown, 1986). High damping capacity is also useful in many sporting goods applications. Here the composite materials are desired for the laminated leaf spring in automobiles. The use of non-recyclable composite components in car manufacturing is not obvious (Duflou *et al*., 2009). Even the sugarcane fibre/polyester composites can be prepared with two forms of reinforcement, i.e. chopped fibres and unidirectional fibres (El-Tayeb, 2008). Hybridization of Glass fibers with natural fibers were also done and used for piping (Recca, 2008). The use of hybrid synthetic and natural fibers gives the hybrid bio composites comparable performance to synthetic fiber composite materials at a reduced cost (Mohanty, 2009).

Hybrid composites are one of the emerging fields in polymer science that triumph attention for application in various sectors ranging from automobile to the building industry (Jawaid and Khalil, 2011).

MATERIALS AND METHODS

Materials: Glass fibers are the most common of all reinforcing fibers for Polymer Matrix Composites (PMC). The Main advantages of glass fibers are low cost, high tensile strength, high chemical resistance and excellent insulating properties (Ahmed and Vijayarangan, 2008). The disadvantages are relatively low tensile modulus and high density (among the

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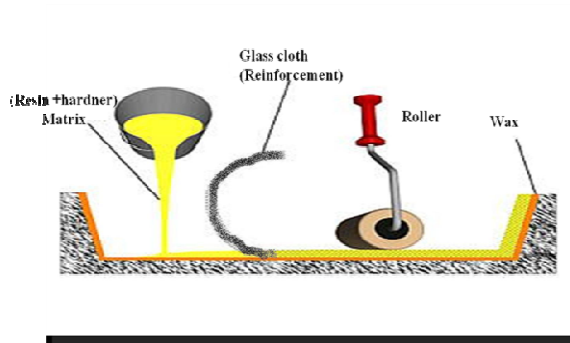
Fig. 1: Hand layup technique for manufacturing composite

Fig. 2: Preparation of resin for the use manufacturing composite

Fig. 3: Cutting of the glass fibre cloth

Fig. 4: Applying resin mix over the woven fiber

Fig. 5: Layering process of laminates one over the other

commercial fibers), sensitivity to abrasion during handling (which frequently decreases its tensile strength, relatively low fatigue resistance and high

Fig. 6: Curing of composites

hardness (which causes excessive wear on moulding dies and cutting tools). The two types of glass fibers commonly used in the Fiber-Reinforced Plastics (FRP) industry are E-glass and S-glass. Another type, known as C-glass, is used in chemical applications requiring greater corrosion resistance to acids than is provided by E-glass. E-glass has the lowest cost of all commercially available reinforcing fibers, which is the reason for its widespread use in the FRP industry. S-glass, originally developed for aircraft components and missile casings, has the highest tensile strength among all fibers in use. However, the compositional difference and higher manufacturing cost make it more expensive than E-glass (Talib *et al.*, 2010). A lower cost version of S-glass, called S-2-glass, is also available. Although S-2-glass is manufactured with less-stringent non military specifications, its tensile strength and modulus are similar to those of S-glass. In this we are selecting the E glass fibers and the Epoxy used is LY556 RESIN. LY556 resin is a bi functional epoxy resin i.e., Diglycidylether of Bisphenol-A (DGEBA). In this project, the hardener used is HY951 HARDNER. This is an aliphatic primary amine, viz., triethylene tetramine-TETA. Before bonding at room temperature and adhesives made from mixture LY 556 resin and HY951 hardener mixed in the ratio of 10:1 by weight.

Method: The oven glass cloth laminate is commercially available is used for making laminates. The cloth was trimmed to correct size. The surface thoroughly cleaned In order to ensure free from oil, dirt, impurity etc. Before bonding at room temperature and adhesives made from mixture LY556 resin and HY951 hardner mixed in the ratio of 10:1 by weight then applied Hand layup technique is used to prepare laminates. Laminates allowed to cure for 24 h at room temperature. Resin based coir/glass hybrid composites were developed using compression moulding followed by hand lay-up technique (Kumar *et al.*, 2009). Fabrication is done according to ASTM D4762-10 (Fig. 1).

Hand Lay-up is an open moulding process. Mould release agent and gel coat are applied to the mould followed by fiber glass strands, mat, or woven roving. Thermosetting resin with a curing agent is applied to the fiber glass reinforcement. Air is removed by roller to insure complete wet out and wet through (Fig. 2 to 6).
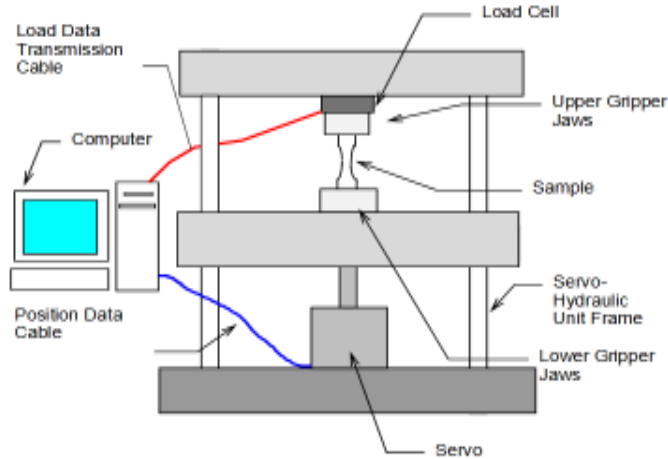
Fig. 7: Tensile test equipment

Table 1: Tensile test specimen dimension

Specimen name	Thickness mm	Width mm	Gauge length mm
GG-1	3	15	50
GG-2	4	15	50
GG-3	5	15	50
GG-4	6	15	50

Table 2: Tensile test results

Specimen name	Max. force KN	Max. stress KN/m^2	Strain (%)
GG-1	3.0256	13.447	6.5433
GG-2	4.2676	14.225	6.8856
GG-3	5.4268	15.053	6.9836
GG-4	9.2723	17.236	7.2755

Max.: Maximum

RESULTS AND DISCUSSION

Tensile test: After the composite material is prepared, the composite material is cut into required specimen dimension for testing using circular saw cutter. Grinding is required for finishing process. The specimen is named as GG-1, GG-2 and GG-3 and GG-4 (Table 1 and Fig. 7 to 9). From the Table 2 and Fig. 10 and 11 it is understood that the stress induced is maximum in the specimen GG-4 and the force it withstands is maximum in GG-4. It means as the thickness increases the stress induced is also increases. The void content will reduce the tensile strength (Jawaid *et al.*, 2011).

Impact test: According to ASTM D 256 the specimens are made for the determination of the impact resistance and impact strength of composite material. The standard tests for these test methods require specimens made with a milled notch.

The specimen is held as a vertical cantilever beam and is broken by a single swing of the pendulum. The line of initial contact is at a fixed distance from the specimen clamp and from the centre line of the notch and on the same face as the notch (Fig. 12).

The impact strength of composite laminate is done according to ASTM D 256. Table 3 and the Fig. 13

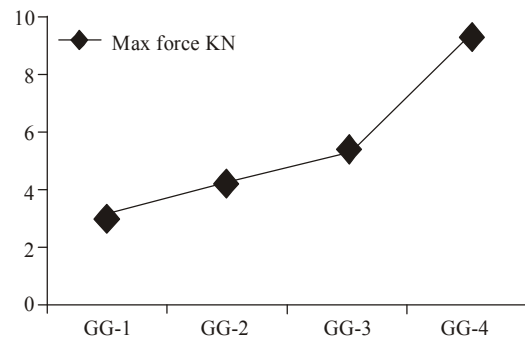Fig. 8: Test specimen for tensile test as per ASTM standard

Fig. 9: Graph showing the tensile test result of composite laminates

shows the variation of impact strength. The impact strength is maximum in GG4 is 31 KJ/m² and minimum in 24 KJ/m² i.e., the impact strength is maximum in the thick laminates and minimum in the thin laminates.

Water absorption test: The specimens are cut as per the ASTM D 570-98 standard for moisture absorption test. The specimens are cleaned and weighed in an electronic balance of 0.00001 g accuracy to monitor the mass during the aging process. The specimen is
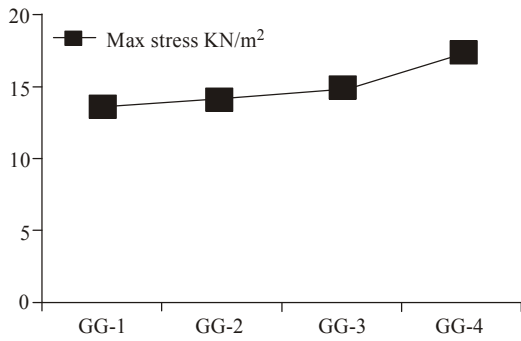
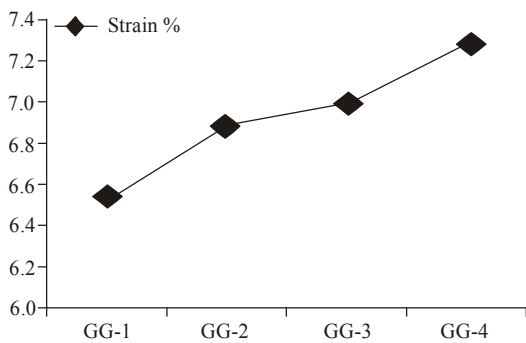Fig. 10: Graph showing the maximum stress of composite laminates

Fig. 11: Graph showing the maximum strain of composite laminates
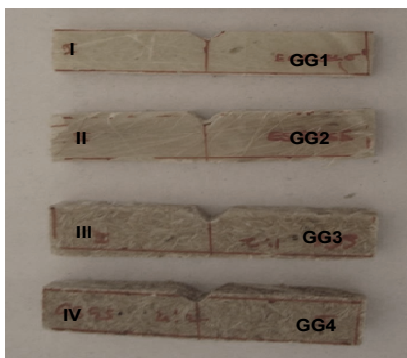

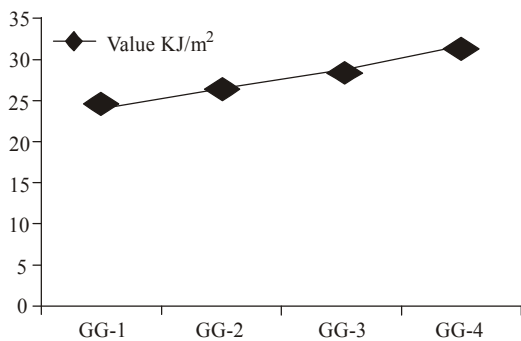Fig. 12: Test specimen for impact test as per

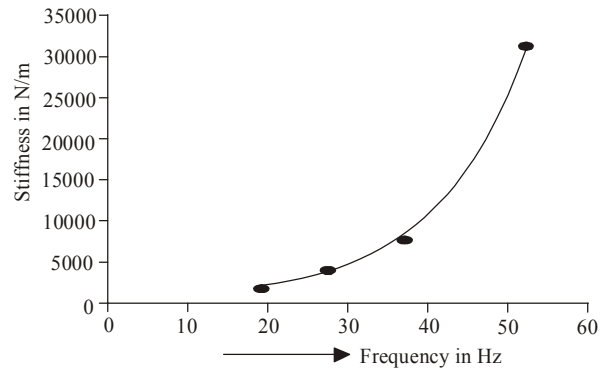Fig. 13: Graph showing the impact test result of composite test specimen

Fig. 14: The graph showing the theoretical frequency and the stiffness of the cantilever type

Table 3: Impact strength test results

Specimen name	Value KJ/m^2
GG-1	24
GG-2	26
GG-3	28
GG-4	31

Table 4: Water absorption test procedure

Procedure	Test description
Water absorption ½ h at 23°C	Test samples are immersed in distilled water at room temperature for 1/2 h
Water absorption 2 h at 23°C	Test samples are immersed in distilled water at room temperature for 2 h
Water absorption 24 h at 23°C	Test samples are immersed in distilled water at room temperature for 24 h

$76.2 \times 25.4 \times 5$ mm^3, five specimens were tested and the average was calculated. Moisture absorption tests were conducted by immersing specimens in a distilled water bath at room temperature and boiling water. At room temperature and boiling temperature, the absorption was monitored at ½, 1, 1 ½, 2, 4, 6, 8, 10 and 24 h, respectively. During the immersion process, the specimens are allowed to rest on one edge at the bottom and entirely immersed. For each observation at each stipulated interval, the specimens are wiped with a clean, dry cloth to remove the excess moisture immediately and then weighed. In the boiling water immersion process, after each immersion, the specimen are brought to room temperature by dipping in cold water for 10 min and then processed further as mentioned above. The moisture content M (t), absorbed by each specimen is calculated as follows:

$$M(t) = \left(\frac{(w_t - w_0)}{w_0}\right)x100$$

where,
w_0 = Dry weight of specimen in g
w_t = Wet weight of specimen in g

The test procedure and the test description are given in the Table 4.

Table 5 to 13 shows the water absorption result for ½, 1, 1 ½, 2, 4, 6, 8, 10 and 24 h, respectively. The

Table 5: Water absorption test (½ h)

Water absorption test ½ h

Samples	Before testing g	After testing g	Formula $M(t) = (\frac{(w_t - w_0)}{w_0})x100$	Avg.
GG1	0.006	0.007	(0.007-0.006) /0.007*100	14.28
GG2	0.019	0.020	(0.020-0.019) /0.020*100	5.00

Avg.: Average

Table 6: Water absorption test 1 h

Water absorption test 1 h

Samples	Before testing g	After testing g	Formula $M(t) = (\frac{(w_t - w_0)}{w_0})x100$	Avg.
GG1	0.006	0.008	(0.008-0.006) /0.008*100	28.57
GG2	0.019	0.021	(0.021-0.019) /0.021*100	9.50

Avg.: Average

Table 7: Water absorption test 1½ h

Water absorption test 1½ h

Samples	Before testing g	After testing g	Formula $M(t) = (\frac{(w_t - w_0)}{w_0})x100$	Avg.
GG1	0.006	0.010	(0.010-0.006) /0.010*100	4.00
GG2	0.019	0.022	(0.022-0.019) /0.022*100	13.63

Avg.: Average

Table 8: Water absorption test 2 h

Water absorption test 2 h

Samples	Before testing	After testing	Formula $M(t) = (\frac{(w_t - w_0)}{w_0})x100$	Avg.
GG1	0.006	0.011	(0.011-0.006) /0.011*100	45.4
GG2	0.019	0.023	(0.023-0.019) /0.023*100	47.3

Avg.: Average

Table 9: Water absorption test 4 h

Water absorption test 4 h

Samples	Before testing g	After testing g	Formula $M(t) = (\frac{(w_t - w_0)}{w_0})x100$	Avg.
GG1	0.006	0.008	(0.008-0.006) /0.008*100	25
GG2	0.018	0.020	(0.020-0.018) /0.020*100	10

Avg.: Average

Table 10: Water absorption test 6 h

Water absorption test 6 h

Samples	Before testing g	After testing g	Formula $M(t) = (\frac{(w_t - w_0)}{w_0})x100$	Avg.
GG1	0.006	0.009	(0.009-0.006) /0.009*100	33.33
GG2	0.018	0.022	(0.022-0.018) /0.022*100	18.18

Avg.: Average

Table 11: Water absorption test 8 h

Water absorption test 8 h

Samples	Before testing g	After testing g	Formula $M(t) = (\frac{(w_t - w_0)}{w_0})x100$	Avg.
GG1	0.006	0.011	(0.011-0.006) /0.011*100	45.45
GG2	0.018	0.024	(0.024-0.018) /0.024*100	25.00

Avg.: Average

Table 12: Water absorption test 10 h

Water absorption test 10 h

Samples	Before testing g	After testing g	Formula $M(t) = (\frac{(w_t - w_0)}{w_0})x100$	Avg.
GG1	0.006	0.013	(0.013-0.006) /0.013*100	53.84
GG2	0.018	0.025	(0.025-0.018) /0.025*100	28.00

Avg.: Average

Table 13: Water absorption test 24 h

Water absorption test 24 h				
Samples	Before testing g	After testing g	Formula $M(t) = (\frac{(w_t - w_0)}{w_0})x100$	Avg.
GG1	0.006	0.008	(0.008-0.006) /0.006*100	25.00
GG2	0.020	0.022	(0.022-0.020) /0.022*100	9.09

Avg.: Average

Table 14: Damping ratio of composites when the laminate ends are treated as cantilever

Laminates (thickness in mm)	Mass in Kg	Cantilever				Damping ratio
		Frequency in Hz		Stiffness in N/m		
		Theoretical	Experimental	Theoretical	Experimental	
3	0.110	19.45	25.72	1642.8	2872.7	1.08
4	0.129	27.62	33.22	38851.0	5620.1	1.27
5	0.139	37.45	44.27	7585.4	10599.8	2.40
8	0.285	52.55	60.16	31070.6	40721.1	5.50

Table 15: Damping ratio of composites when the laminates ends are treated as fixed

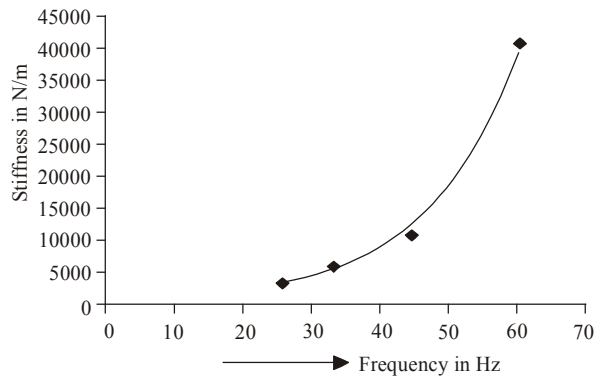| Laminates (thickness in mm)	Mass in kg	End fixed				Damping ratio
		Frequency in Hz		Stiffness in N/m		
		Theoretical	Experimental	Theoretical	Experimental	
3	0.110	110.42	123.52	52.94×10^3	66.25×10^3	0.85
4	0.129	156.99	162.45	125.5×10^3	134.3×10^3	1.07
5	0.139	212.90	230.53	245.1×10^3	287.4×10^3	1.53
8	0.285	298.74	313.69	1004.1×10^3	1107.1×10^3	1.85

Fig. 15: The graph showing the experimental frequency and the stiffness of the cantilever type
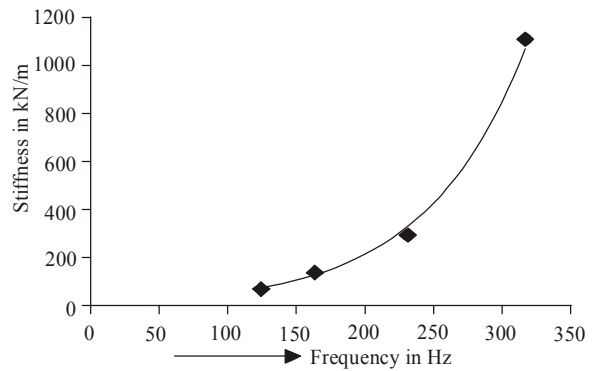

Fig. 17: The graph showing the experimental frequency and the stiffness of the both end fixed type
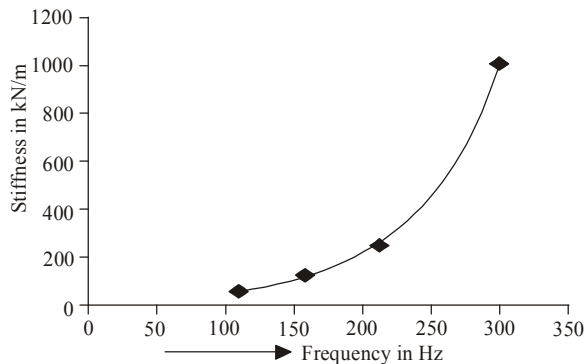

Fig. 16: The graph showing the theoretical frequency and the stiffness of the both end fixed type

result obtained from the Table 5 to 13 shows that the moisture content increases as the hour of absorption increases.

Structural damping: The damping ratio is calculated for fixed and cantilever type of laminates. Table 14 and 15 shows the damping properties such as frequency and the stiffness obtained of the composite laminates which were experimentally and theoretically calculated. The composite laminates are tested for two condition:

- Cantilever
- Both the ends fixed

For carrying out the test, the specimen is connected to the FFT analyzer and to the system. The

accelerometer and force sensor is connected to the FFT analyzer.

Figure 14 to 17 shows the graphical representation of theoretical and experimental result of the frequency and stiffness of both cantilever and both end fixed. The highest frequency is recorded and the high stiffness is observed when the both the ends are fixed. From basic vibration theory, high stiffness results in a high frequency of vibration. Since the rigidity of the system drops in the case of the cantilever, the decrease in frequency has occurred. For the same thickness of 8 mm of the laminates the damping ratio is 5.5 for the cantilever case and 1.85 for the fixed type.

CONCLUSION

From the test conducted and the result obtained it is suggested that the metal can be replaced by the composite materials, since the mechanical properties of the composite materials are similar to that of the steel for the use of automobile leaf spring. The damping ratio of the fixed end case is lower than the cantilever type. A finite element analysis of composite plate based on the first order shear deformation theory is proposed for the free vibration of composite plates with simply supported boundary conditions as suggested by Lynda and Fayal (2011). This will enable us to know the deformation and the frequencies of the composite plates.

The effect of the additives like methyl ethyl ketone peroxide and cobalt naphthenate improves the mechanical properties (Nazareth da Silva *et al.*, 2001). Further the hybrid composite material can be fabricated and its mechanical properties can be found as suggested by Renuganth Vartharajoo (Khanam *et al.*, 2010). Different chemically modified sisal fibres have been used in addition to glass fibers as reinforcements in polyester matrix to enhance the mechanical properties of the resulting hybrid composites (Vaidya *et al.*, 2003). The unwanted materials can also be utlised as fibre material in composites and that can be used in the aerospace industries (Tungjitpornkull *et al.*, 2007). Alos some more aeroelastic analysis can be done for further applications.

In this the effect of stacking sequence on tensile, impact and water absorption were analyzed for E-glass fiber reinforced epoxy composites have been experimentally evaluated. From results of this study the following conclusions are drawn. 1. Layering sequence significantly affects the tensile strength i.e., the sample GG1 and GG4 of tensile strength is 13.447 and 17.236 KN/m^2, respectively. For the same weight fraction glass fiber layering has little effect on impact strength i.e., GG1 and GG4 of impact strength is 24 and 31 KJ/m^2, respectively. From the above a conclusion it is arrived that to have more strength and

stiffness, the orientation of fibers can be changed. The Hybrid Composites can be used to obtain the required mechanical properties which can be used for different applications in the field of mechanical, Aero space and Automotive.

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