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Mechanical Properties and Vibration Damping Characteristics of Carbon/Glass Fiber Reinforced Epoxy Hybrid Polymer Composites

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ABSTRACT

This paper aims to study the mechanical properties and vibrational damping characteristics of carbon/glass fiber reinforced with filler SiC Epoxy Hybrid polymer composite, which can be used in many applications and in engineering structures. The properties are joined together in one material by utilizing distinctive filaments in one resin matrix is to create and investigations the carbon/glass fiber fortified epoxy cross breed composite with addition of silicon carbide fillers with various weight fractions (3%,6%,9%). The silicon carbide filler are used reinforcement and fabricated using Hand lay-up and compression molding technique. The laminated specimen are tested as per ASTM standards to investigate various mechanical properties and vibration damping characteristics were evaluated using vibration tester to study various vibration characteristics like natural frequency, damping ratio, loss factor, for composite specimen .The results indicates that understand the improvement in the mechanical properties and damping characteristics improved with increase in weight percentage of silicon carbide filler reinforcement content.

Keywords— Compression molding, Glass fiber, Epoxy, SiC fillers, Vibration, Damping.

1. INTRODUCTION

A composite material consists of two or more constituents with improved mechanical properties. When the matrix is prepared appropriately to meet the end use, new combined material will exhibit better strength than each individual material. In current periods there has been a significant growth in the large scale production of composites because of their remarkable properties. These are used in varying applications such as in aerospace, automotive and chemical industry due to their good combination of properties. Fibers reinforced polymer composites are used for producing number of mechanical devices such as gears, wheels, brakes, clutches, bush bearing and seals [1].

Improving the materials strength by making hybrid composites gains importance in modern days. This has a huge advantage over other materials because of its properties such as low weight better strength, less heat and electrical conductivity, resistance to wide range of chemical agents. The technique involves blending of different fibers, resins with fillers into a single matrix to produce hybrid composites. When a hybrid composite contains different types of fiber, the advantages of one fiber would counterpart the other. The properties of the hybrid composite mainly depends on the nature of the fiber such as its content, length, orientation, fiber to matrix bonding and arrangement fibers. The strength of the hybrid composite depends on the failure strain of individual fiber used.

Properties of the vibration damping hybrid composites such as its good strength, low density and high performance to cost ratio with rapid clean processing has many advantages especially in structures. Some of the real-time application includes their applications in aerospace, automotive and chemical industries [2] owing to their properties which includes high strength-to-weight and stiffness-to-weight ratios.

Polymeric composites made of reinforced Glass fiber usually have reduced wear resistance and high friction; this has provoked researchers to prepare the polymers with fibers/fillers. This helps in using the composites for varying range of practical applications thereby providing both economical and functional benefits to the manufacturing and the end users. Literature review shows various works have been conducted by varying its profiles, dimensions, natures and compositions of fibers.

2. REVIEW OF LITERATURE

Experiments were conducted on Glass fiber / Carbon fiber with different compositions along with silicon carbide to study the properties. Results show that the glass fibers fail more quickly than the carbon fibers and the mechanical properties of composite materials mainly depends upon the structure of the material. Hybrid composites fabricated by vacuum bag method shows better mechanical properties like micro hardness, tensile and flexural strength of hybrid composites as per ASTM standards. The micro hardness of carbon fiber reinforced composite is higher than the other composites. The inclusion of carbon fiber mat reinforced polymeric composite significantly enhanced the ultimate tensile strength, yield strength and peak load of the composite. The ductility of carbon fiber reinforced composite is higher than the other composites [3].

Different types of composite laminates were investigated on tension, compression and three-point-bending in a study. Plain glass fiber composite, glass/carbon (50: 50) fiber reinforcement was used either by placing the carbon layers at the exterior or by placing different fiber types alternatively. This effectively improved the tensile, compressive and flexural strength of the. With the same hybrid composition, the stacking sequence did not show noticeable influence on the tensile properties but affected the flexural and compressive properties significantly [4].

In [5] this study, to obtain a high-performance material, hybrid composites were designed by lamination pairing of carbon/aramid fiber and carbon/ glass fiber. The various laminating structures were manufactured efficiently using VARTM. The mechanical properties arising from the pairing effect were investigated using tensile and bending tests. Results showed an increase in tensile strength, the central laminating condition can be seen to play an important role in the stacking design of hybrid composites.

Orientation schemes of carbon and E-glass fibers was compared with Hybrid composites. Results of the study [6] shows mechanical performance is better than that of the others hybrid combination in terms of tensile and flexural mechanical performance. Hybrid composites with lighter weight and higher strength are one of the key to moderate the shortage of petrol fuel as well as reduce the environmental burden of automotive vehicles or aerospace structural.

In [7] three different composite materials namely, glass and carbon fiber reinforced epoxy matrix hybrid composite, glass fiber reinforced epoxy matrix composite and carbon fiber reinforced epoxy matrix composite were processed by filament winding technique and studied.

The result shows, flexural strength of hybrid composite is significantly higher as compared to other two materials. Thus, the composite showed an appreciable influence of glass and carbon fibers. With this property obtained from hybrid composite, it is clearly suitable for structural applications such as aerospace applications. The flexural strength of glass fiber reinforced composite is significantly higher than carbon fiber reinforced composite; this is due to the brittleness of carbon fibers in spite of their high values ultimate tensile strength.

3. FABRICATION DETAILS

Carbon fiber and E-glass (Epoxy-glass) fiber with SiC was selected as reinforcement and epoxy and matrix material. Reinforcement: Bi-directional carbon fiber 330 GSM and Bi-directional glass fiber 600 GSM. Filler: Silicon Carbide (SiC), Matrix: Epoxy resin - Araldit LY 556, Hardener - Araldit HY 951.

A. Fabrication of Hybrid composites

Density (kg/m3) = mass (m) / Volume (V)   (1)

Fabrication of laminates (dimension = 300x125 mm) were made by hand layup technique at ambient temperature. Carbon fiber, glass fiber and silicon carbide was mixed in different proportions along with epoxy resin as shown in the Table I. Equal amount (40%) of epoxy resin is taken and Araldit HY 951 is added to the resin and mixed thoroughly. The fibers were positioned in the open mold and the mixture made of resin and hardener is brushed uniformly over the glass and carbon layers alternatively. The excess amount of mixture and trapped air is removed by passing roller to complete the laminate structure. To evenly distribute the resin, laminates were subjected to compression molding technique.

Table 1. Composition of the hybrid composites

Sample No	Carbon Fiber		Glass fiber		Silicon Carbide		Epoxy resin % weight (gm)
	% weight	No. of Layers	% weight	No. of Layers	% weight	Amt. added (gm)	
1	60	14	0	0	0	0	40
2	0	0	60	24	0	0	40
3	30	7	30	12	0	0	40
4	30	7	27	11	3	11	40
5	30	7	24	10	6	22	40
6	30	7	21	9	9	33	40

B. Laminating using compression molding technique

First the mold surface was cleaned with propanone so that it does not bond with the laminate. Six different laminates with different carbon/glass fiber (Fig.1) with filler proportions of silicon carbides are fabricated using compression molding technique. Typical representation of the technique was shown below in the Fig.2.

Fig.1 The glass fiber and carbon fiber

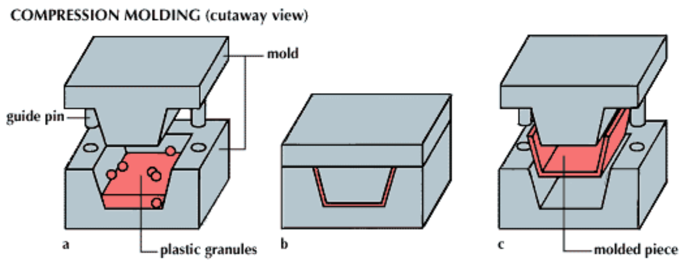

Fig.2 Representation of Compression Molding

Compression molding is a high-volume, high-pressure method suitable for molding complex, high-strength fiberglass reinforcements. This technique was adopted in the present study because it is one of the lowest cost molding methods compared with other available methods such as transfer molding and injection molding.

As compression molding is typically used to make larger flat parts, composites were prepared using the same technique. The laminates prepared were then subjected to molding by positioning them in the mold cavity and the heated platens are closed by a hydraulic ram. Sheet molding compound (SMC) is conformed to the mold formed by the applied pressure and heated until the curing reaction occurs. The mold is then cooled at room temperature for more than 12 hours and then subjected to observe the mechanical and vibrational characteristics.

C. Tensile test

The composite laminates fabricated as explained above was then cut to make required shape and dimension (ASTM D3039 - 250 X 25 X 3 mm) using a saw cutter. The edges of composite specimen are finished by using emery paper. To observe the tensile strength; test specimens were prepared according to the ASTM standard. The procedure for testing the tensile strength involves fixing the specimen in the machine using proper fixing equipment and the tensile load is applied till the fracture occurs. The tensile force is recorded with respect to the increase in gauge length. The experiment is repeated for several times. The prepared specimen as per ASTM standard and the fractured specimen after the application of tensile load is shown in the Fig.3 below.

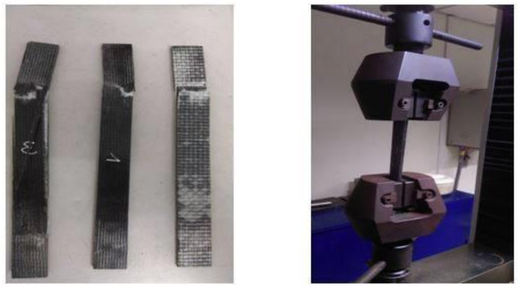

Fig.3 Tensile Test

D. Flexural test

The flexural test is carried out using flexural specimens which were prepared as per ASTM standard (ASTM D 790 – 125 X 13 X 3 mm). The experiments are conducted by using three point flexural tests and it is the most common test method used for studying the composites. The deflection of the specimen is measured by means of cross head position and the displacement and the flexural strength are measured. The specimen prepared for conducting the flexural test and the fractured specimen after the testing are presented in Fig. 4. The experiments are carried out at ambient temperature.

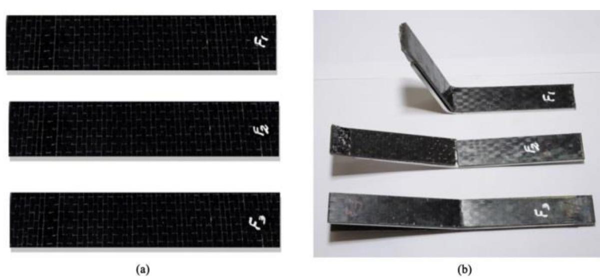

Fig.4: Flexural Test

E. Impact test

The impact test specimens were prepared as per the required dimension specified by ASTM standard (ASTM D 256 – 65 X 13 X 3 mm). In the testing process, the specimen is fixed in the impact testing machine and the energy is applied by means of an impact load, until the fracture occurs on the specimen. The impact test is used to measure the energy required for breaking the materials. The specimen used for conducting the impact test and the fractured specimen are presented in Fig.5.

Fig.5: Impact Test

F. Vibration Test

Following are the Dimension and properties of the beam used in vibration testing,

Table 2.

Length(mm)	L	250
width(m)	B	25
Thickness(m)	T	3
Young's modulus(GPa)	Ec	34.40
Density(g/cm3)	C	1.98

The above specimens prepared as per the dimensions mentioned above were subjected to Free vibration test and forced vibration test as discussed in the following sections and results were recorded.

G. Free Vibration

The system was displaced from its mean position and released. The resulting free vibrations are recorded. From this, the resulting information regarding the natural frequency and damping has been obtained. In practice, a mechanical system under test is rapped by impact from a light hammer to include free vibrations. Vibration testing apparatus was shown in Fig.6.

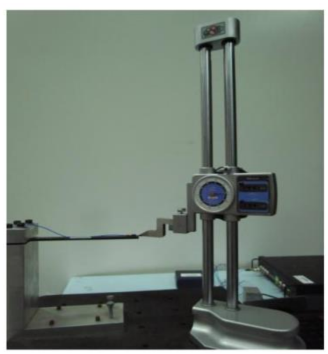

Fig.6 Free Vibration testing apparatus

H. Forced Vibration

In Forced vibration test a time-varying disturbance is applied to a mechanical system. In our case, External forces were created using mini shaker. The resulting vibrations are recorded. From this the information regarding the frequency and damping has been obtained. Representation of an experimental set up was shown in the Fig.7 below.

Fig. 7: Representation of Forced Vibration Testing apparatus

4. RESULTS AND DISCUSSION

The fabricated composites subjected to mechanical and vibration tests showed the following results. Results of the Tensile strength test are shown in Table 3.

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Table 3 Tensile Test Results

Sample	Ultimate Tensile Strength (Mpa or N/mm)	Ultimate Tensile Load (kN)
1	260	33.71
2	230	29.83
3	360	46.69
4	420	54.47
5	490	63.51
6	510	66.14

It is observed that, sample 6 showed highest strength of 510 N/mm may be because of the 30% carbon fiber, 21% glass fiber with filler 9% even though sample 2 received a load of 29.83 N. Results of the Flexural strength test is shown in Table 4 .

From the results it is again evident that sample 6 is effective with its flexible properties due to the above said composition.

Table 4 Flexural Strength Results

Sample	Flexural Load(kN)	Deflection At Peak (mm^2)	Flexural Strength (Mpa)
1	4.11	6.81	593
2	4.23	7.70	613
3	5.76	8.63	727
4	6.30	10.40	813
5	7.28	12.32	878
6	9.13	13.78	958

Table 5 Impact Test Results

Sample	Absorbed Energy (joules)			Average
1	12.0	13.5	13.0	12.83
2	12.0	12.0	12.0	12.0
3	14.0	13.5	14	13.83
4	15.0	14.7	14.5	14.73
5	16.5	16	16.5	16.33
6	17.5	17.5	17	17.33

Results of the Impact test results are shown in Table IV. It is once again apparent that sample 2 showed better results when comparing to the values observed for other samples tested. The damping property of the composite was done by both free and forced vibration test. Table 5 shows the results obtained from the test.

Table 6 Vibrational Characteristic Results

Sample	Loss factor (§)	Damping ratio (€)	Natural Frequency (Hz)
1	0.2177	0.0346	26.6
2	0.1963	0.0275	24.3
3	0.2778	0.0378	27.1
4	0.3256	0.0423	28.5
5	0.3797	0.0484	29.2
6	0.4163	0.0512	30.3

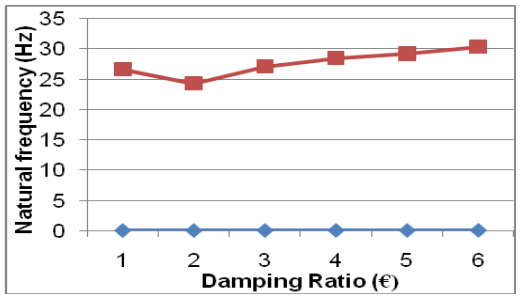

Fig.8 Graphical representation of Damping Ratio Vs Natural frequency

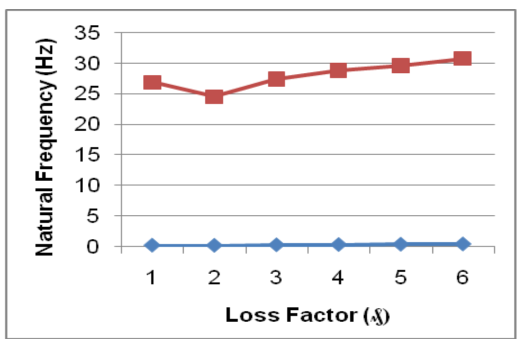

Fig.9 Graphical representation of Loss factor Vs Natural frequency

From the above graphs (Fig. 8 and 9), it is observed that sample 6 showed better damping properties when compared to other compositions prepared and subjected for testing. This may be due to the highest percentage of SiC present in the mixture prepared along with carbon and glass fibers.

5. CONCLUSION

Study concludes that, Sample 6 (30% carbon fiber, 21% glass fiber with filler 9%) has better properties when comparing to other samples with varying concentrations of Carbon fiber, Glass fiber with SiC. Further subjecting sample 6 to abrasive wear test and acoustic test would help us to know their mechanical properties and vibrational characteristics much better. Also, studying the morphological features through SEM/TEM would help us to know the arrangements of the fiber in the composite to extend its various applications.

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