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Vibrational Characteristics of Chopped Glass Fibre and Flyash Filled Epoxy Composites

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Abstract - *Polymer matrix composites are promising candidates to applications due to the possibility of tailoring their properties with special fillers and fibres. Filler filled & fibre reinforced polymer matrix composite systems are used in many automotive parts and in a wide range of applications spanning from electronic products such as printed circuit boards to advanced aerospace structures and reusable launch vehicles. In particular, mechanical properties and vibrational characteristics of Polymer Matrix Composites can be changed by the use of fillers in combination with fibers. The ability to tailor the composites for specific end applications has been one of the key factors in their usage being expanded in a comparatively shorter period. However, many challenges need be overcome before a successful deployment of the composite component is made. . Therefore research in this area will lead to better performance of machines and other components. The incorporation of fillers in polymer could provide a synergism in terms of improving mechanical properties which has not been adequately explored so far. The present study was focused on preparation of wooden mould for casting the specimen, investigating Mechanical - Tensile, Hardness, and Vibrational characteristics of thermosetting based Epoxy composites and the effect of incorporation of fly ash and chopped glass fibers on microstructure, hardness, frequency, damping ratio and mode shapes are determined and analyzed. The main aim was to investigate the effect of chopped fiber and percentage of filler on the mechanical and vibrational characteristics of epoxy composites.*

Key Words: Composites, epoxy, chopped fibres, flyash, vibrational characteristics, mechanical properties

1. INTRODUCTION

Composites are one of the most widely used materials because of their adaptability to different situations and the relative ease of combination with other materials to serve specific purposes and exhibit desirable properties. In recent years, composites made of natural fibers have received increasing attention in light of the growing environmental awareness. Also because of their low density, good mechanical performance, unlimited availability and problem free disposal, natural fibers offer a real alternative to the technical reinforcing fibers presently available.

Epoxy resins have been used successfully in a wide range of applications spanning from electronic products such as printed circuit boards to advanced aerospace structures and reusable launch vehicles. Epoxy resins have been synthesized to meet the demands of defence, aerospace and electronics industries. This is primarily due to its fluidity, low shrinkage during cure and ease of processing. The cured resins have good mechanical properties (i.e. ultimate tensile strength, modulus, elongation at break, toughness and fatigue resistance), low moisture absorption and relatively poor thermal stability and flame resistance.

Structural vibration testing and analysis contributes to the progress in many industries, including aerospace, auto-making, manufacturing, wood and paper production, power generation, defence, consumer electronics, telecommunications and transportation. The most common application is identification and suppression of unwanted vibration to improve product quality. Modal analysis is the study of the natural characteristics of structures. Understanding both the natural frequency and mode shape helps to design my structural system for noise and vibration applications. We use modal analysis to help design all types of structures including automotive structures, aircraft structures, spacecraft, computers, etc.

Itishree Mishra & Shishir Kumar Sahu [1] studied the free vibration of woven fiber Glass/Epoxy composite plates in free-free boundary conditions. The specimens of woven glass fiber and epoxy matrix composite plates are manufactured by the hand-layup technique. Elastic parameters of the plate are also determined experimentally by tensile testing of specimens using Instron 1195. An experimental investigation is carried out using modal analysis technique with Fast Fourier Transform Analyzer, PULSE lab shop, impact hammer and contact accelerometer to obtain the Frequency Response Functions. Also, this experiment is used to validate the results obtained from the FEM numerical analysis based on a first order shear deformation theory. The effects of different geometrical parameters including number of layers, aspect ratio, and fiber orientation of woven fiber composite plates are studied in free-free boundary conditions in details. This study may provide valuable information for researchers and engineers in design applications.

Brian Schwarz & Mark [2] includes all of the main topics associated with experimental modal analysis (or modal testing), including making FRF measurements with a FFT analyzer, modal excitation techniques, and modal parameter estimation from a set of FRFs (curve fitting). Modern experimental modal analysis techniques have been reviewed in this paper. The three main topics pertaining to modal testing; FRF measurement techniques, excitation techniques, and modal parameter estimation (curve fitting) methods were covered. FRF based modal testing started in the early 1970's with the commercial availability of the digital FFT analyzer, and has grown steadily in popularity since then. The modern modal testing techniques presented here are just a brief summary of the accumulation of the past 30 years of progress.

Mahesh Dutt & Shivanand [3] presented a combined finite element and experimental approach used to characterize the vibration behavior of composite laminates. Specimens are made using the hand-layup process. Graphite and Kevlar fibers are used as reinforcement in the form of bidirectional fabric and general purpose Epoxy resin as matrix for the composite material of beams. Experimental dynamic tests are carried out using specimens with different fiber orientations. Also, these experiments are used to validate the results obtained from the finite element software ANSYS. Two types of laminated fibers composite plates with Graphite and Kevlar of 2mm thickness were fabricated and their vibration characteristics investigated by modal impact vibration tests. For the laminated composite specimens, the change in the vibration properties is more significant with change in boundary conditions, but is less sensitive for thickness consideration. The natural frequency of the laminated beams increases with change in boundary conditions. The natural frequency of the lowest flexural bending mode significantly increases with the increase of the composite specimen when both edges of the specimens are clamped. When they are fixed at one end, the frequency of the bending mode somewhat decreases with the increase of the specimen curvature. This is in tune with the known behavior of the homogeneous nature of specimens. At the same time, the natural frequencies of higher order modes increases slightly with the change in boundary conditions. As can be seen from the graph, Kevlar fibers have the best damping capacity which makes it very useful in various applications.

Sharayu et al. [4] performed extensive experimental works to investigate the free vibration of woven fiber Glass/Epoxy composite plates in free-free boundary conditions. The specimens of woven glass fiber and epoxy matrix composite plates are manufactured by the hand-layup technique. Elastic parameters of the plate are also determined experimentally by tensile testing of specimens. An experimental investigation is carried out using modal analysis technique, to obtain the Natural frequencies. Also, this experiment is used to validate the results obtained from the FEA using ANSYS. The effects of different parameters including aspect ratio, and fiber orientation of woven fiber composite plates are studied in free-free boundary conditions in details. The Percentage of error between experimental value and ANSYS package is within 15%. The difference is probably due to uncertainty in elastic properties and other described reasons. For Free-free boundary condition it is found that the natural frequency of plate increases with the increasing of aspect ratio. Natural frequency decreases as the ply orientation increases up to [45/-45] and again increases up to [30/-60].

Ahmad Mujahid et al. [5] investigated with natural fiber that will be used is coconut coir as filler and the natural latex resin as a matrix material. There are 4 percentages of the coir fibre that will be used to fabricate the composites which 40% wet, 50% wet, 60% wet and 70% wet of coir fibre. Experimental Modal Analysis (EMA) will be used to determine the dynamic characteristic of the composite (i.e. natural frequency, damping ratio and mode shape). For all the cases, the plate only experiences the global vibration where the whole structure is vibrating. The first five mode shapes of each percentage of coir fibre were observed which can be identified from 39.8 Hz until 985 Hz. From the result, the natural frequencies of 40% wet fibre are observed where can be identified from frequency 315 Hz until 985 Hz. The natural latex with the 40% volume of coir fibres shows a slightly higher frequency compared to 70% volume of coir fibres only for the second until five mode frequency. Somehow for the higher mode, it founds that the natural latex with 70% fibers volume prove to have a higher value. The results were found that the dynamic characteristics are greatly dependent on the volume percentage of fibers. From the result, it can be concludes that the sample with 40% coir fiber gives the highest value of natural frequency which is 315 Hz to 985 Hz compared the others composition. The increase of coir fibers will make the composite tend to have low stiffness and ductility. The damping ratio was found to be increased by incorporation of coir fibres which giving an advantage to the structure in reducing the high resonant amplitude.

Prabhakaran [6] investigated free vibration and the effect of stacking sequence on tensile, impact and absorption properties of composite laminates has been investigated experimentally. Effect of stacking sequence on tensile, impact, water absorption and vibration analysis of glass fiber reinforced epoxy composites have been experimentally evaluated. From results layering sequence significantly affects the tensile strength i.e. the sample GG1 and GG4 of tensile strength is 13.447 KN/m2 and 17.236 KN/m2 respectively. For the same weight fraction glass fiber layering has little effect on impact strength i.e. GG1 and GG4 of impact strength is 24KJ/ m2 and 31 KJ/ m2 respectively. Increasing the thickness of the specimens results in an increase in the natural frequency of the composite panel (directly proportional to the stiffness of the member). The boundary conditions also had a considerable effect on the natural frequency of the composite panel. This information can be effectively used to design composite panels.

Kishore et al. [7] studied the impact behavior of epoxy specimens containing 10% by volume of fly-ash particles with their surface treated for improving or decreasing adhesion is studied. The resulting behavioural patterns are listed and compared to those of composites containing untreated fly-ash particles and unreinforced (i.e. neat) epoxy. It was noticed that samples involving adhesion-increasing (i.e. acetone and silane) treatments show greater absorption of energy and maximum load compared to untreated samples and those subjected to adhesion-reducing treatments. Ductility index, however, showed a reversed trend with adhesion-reducing treatment yielding the highest value. In contrast, the energy absorbed was highest for neat resin and lowest for oil surface bearing ash particulate composites. Scanning electron microscope examination of the failed samples was carried out to obtain information on the fracture features with the aim of correlating microstructure to impact response. Thus, the higher ductility indices cases are shown to be distinct and different from composites containing other surface treatments for fillers. Treatment of particulate fillers to improve their adhesion characteristics to the matrix improves the overall properties of the system, especially strength and load bearing capacities. Among the various treatments, the silane treatment was found to be quite effective. Acetone-cleaned fly-ash particulate also yielded comparable results.

Keshavamurthy et al. [8] worked on preparation of specimens in the laboratory using vacuum bag technique with bi-woven epoxy glass as fiber & with epoxy resin as an adhesive. The specimens are prepared for testing as per ASTM standards to estimate the tensile properties. Stacking Experiments were conducted on Glass/Epoxy laminate composite specimens with varying fiber orientation to evaluate the tensile properties. It is observed from the result that glass/Epoxy with 00 fiber orientation Yields' high strength when compare to 300 & 450 for the same load, size & shape In addition, he conducted failure analysis for glass/Epoxy to evaluate different failure modes and recorded. Finally we observe, though glass/epoxy with 00 orientation have higher strength, stiffness and load carrying capacity than any other orientation. Hence, it was suggested that fiber orientation with 00 is preferred for designing of structures like which is more beneficial for sectors like, Aerospace, automotives, marine, space etc.

Samuel John & Rajendra Prasad [20] In this paper the glass fiber reinforced epoxy composite is manufactured into six different parts each having ratios of glass fiber to epoxy resin as 0:100, 20:80, 40:60, 60:40, 80:20, 100:0 respectively and are compared for ultimate tensile strength, impact strength and flexural strength of the material by conducting experiment such as tensile test, flexural test and impact test. From Tensile strength table we conclude that the composite material shows higher tensile strength with the percentage increase in glass fiber. The material with low percentage of glass fiber and high percentage of epoxy has less tensile strength. And the material with high percentage of glass fiber and low percentage of epoxy has high tensile strength. From impact test table we conclude that the composite material with the higher percentage of glass fiber shows high impact strength. The material with low percentage of glass fiber and high percentage of epoxy has less impact strength. And the material with high percentage of glass fiber and low percentage of epoxy has high impact strength. From flexural test table we conclude that the composite material with the higher percentage of glass fiber shows high flexural strength. The material with low percentage of glass fiber and high percentage of epoxy has less flexural strength. And the material with high percentage of glass fibre and low percentage of epoxy has high flexural strength.

In the present research study attempts are made to study the mechanical and vibrational characteristics of fly ash and chopped glass fiber filled epoxy composites.

1.1 Materials and Experiments

Specimen are cut from composite sheets of dimensions 300 X 300mm and 3mm thick. The composite sheets of varying concentrations of flyash and chopped glass fibres, are made using wooden mounds. The table below gives the configurations of the various composite sheets fabricated.

Specimen	Epoxy	% of Chopped Glass Fibre	% of Flyash
01	100	0	0
02	99	0.5	0.5
03	98	1	1
04	97	1.5	1.5
05	96	2	2

Table 1 : Weight Percentage of resin & fillers

The table indicates the weight percentages of the resin and fillers used in the particular specimen.

The specimens of required dimensions for the vibration test, tensile test and micro hardness tests are cut using the wire cutting machine.

The different mode shapes of the specimens are obtained using the FFT Analyzer. A Fast Fourier Transform is an efficient algorithm to compute the Discrete Fourier Transform (DFT) and its inverse. There are many distinct FFT algorithms involving a wide range of mathematics, from a Simple complex – number arithmetic to group theory and number theory. The input signal is digitized at a high sampling rate, similar to a digitizing oscilloscope. FFT quickly performs a Discrete Fourier Transform which is the practical application of Fourier transforms. Impact testing is a fast, convenient, and low cost way of finding the modes of machines and structures.

The following equipment is required to perform an impact test

1. An impact hammer with a load cell attached to its head to measure the input force.

2. An accelerometer to measure the response acceleration at a fixed point & direction.

3. A 4 channel FFT analyzer to compute FRFs.

4. Post-processing modal software for identifying modal parameters and displaying the mode shapes in animation.

The Tensile test is conducted on a Universal Testing Machine. The specimens are cut according to ASTM D3039. The specimen is mounted between the two grippers and the load is slowly applied. The load corresponding to deformation is noted down. This is repeated for the other specimens.

Vickers micro hardness test was used to examine the micro hardness of epoxy/chopped glass fibre composite samples with different chopped glass fibre and fly ash contents.

2. Results and Discussions

2.1 Vibrational Characteristics

Experimental Modal Testing of epoxy/chopped glass fibre with fly ash composite specimens with five different percentage variation of Chopped glass fibre and fly ash was investigated and the results are tabulated as shown in Table 4.6 .

The Specimen for the Vibrational test was cut to the dimension of 300x300x3 mm. The specimen was divided into 42 nodes, each of 50mm .The specimen was mounted as a cantilever beam on the frame as shown in the figure .The accelerometer, which is connected to the system is fixed on the specimen at suitable point. An impact hammer is used to impact force on the node.

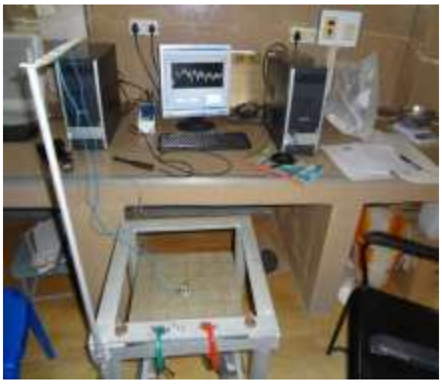


Figure 1: FFT Analyzer Setup

The Table 2 shows different modes of vibration and their corresponding to Mode I for 0% , 0.5% , 1% , 1.5% and 2% of CGF + FA respectively. Five modes of vibration have been noted for each specimen. The first mode is bending, second mode is twisting and other modes are combination of bending and twisting. As the mode no increases, there is an increase in frequency also. The vibration of the specimen in top and bottom position from the neutral position is shown in table 2.

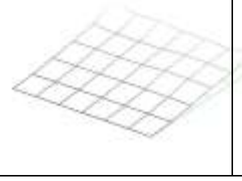
SPECIMEN 1	Mode : 1 Freq : 15.052 Hz Damp Ratio : 1.09 %	TOP 	BOTTOM 
SPECIMEN 2	Mode : 1 Freq: 15.7348 Hz Damp Ratio : 0.828 %	TOP 	BOTTOM 
SPECIMEN 3	Mode : 1 Freq: 14.617 Hz Damp Ratio : 1.002 %	TOP 	BOTTOM 
SPECIMEN 4	Mode : 1 Freq: 16.853 Hz Damp Ratio : 0.819 %	TOP 	BOTTOM 
SPECIMEN 5	Mode : 1 Freq: 17.693 Hz Damp Ratio : 0.90 %	TOP 	BOTTOM 

Table 2: Modes of Vibration – Mode I of the specimens

From the result, the natural frequencies of 2% CGH+FA can be identified from frequency 17.693 Hz until 218.705 Hz. According to the theoretical formulation for natural frequency, the natural frequency of the structure depends on the stiffness and the mass of the structure. Increasing of the stiffness will influence the natural frequency which gives the high value. The mass value will reduce the natural frequency of the structure.

The damping ratio of each sample are inconsistent there are some parameters that will affect the value of damping ratio which are stiffness, mass and damping coefficient. Adding some reinforcement in the sample which is chopped glass fiber obviously gives the structure vibrating in less oscillatory motion. This indicates that, the Chopped glass fiber is not equally flattened on the structure. Therefore, there are certain locations of the structure have high fiber while the other locations have less fiber. That is the reason of inconsistency of damping ratio. From the result, epoxy/ chopped glass has max damping ratio of 1.24%

Mode No	0% CGF +FA	0.5% CGF +FA	1% CGF +FA	1.5% CGF+FA	2% CGF +FA
1	15.052	15.734	14.617	16.853	17.693
2	35.083	36.898	34.818	36.882	37.609
3	95.553	98.344	96.863	106.094	99.046
4	109.571	106.347	107.3993	140.039	106.211
5	137.589	139.057	138.007	220.808	218.705

Table 3: Comparison of frequencies of vibrational test

2.2 Tensile Test

The tensile strength values for the specimens are as shown in the table.

Specimen No	Tensile strength in N/mm^2	% of elongation
0% CGF + FA	17.75	0.72
0.5% CGF + FA	19.67	1.13
1% CGF + FA	11.05	1.01
1.5% CGF + FA	9.75	0.92
2% CGF + FA	13.65	0.87

Table4: Tensile Test Results.

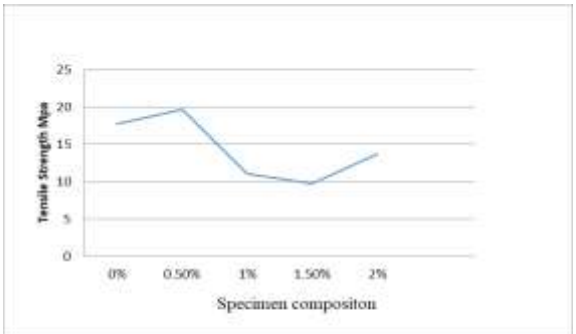


Figure2: Tensile strength vs specimen composition

The effect of weight fraction of fiber on the tensile strength of the composite is shown in Table 4.7. As the weight fraction of fiber increases in the composites up to 0.5%, the tensile strength of the sample increases up to 19.67 MPa. Also it can be seen that the tensile strength of the composite decreases with increase in filler content. It is depicted in figure 4.10 From the tensile test, it was found that 0.5 % specimen has the higher tensile strength as compared to other specimen. There is an increase of tensile strength for 0.5% specimen of 2% and gradually decreases as the glass fiber content increases. 0.5% is considered to have higher tensile strength since the chopped glass fiber has been uniformly distributed.

2.3 Micro Hardness Test

The hardness of the samples is as shown in Table and, that by using the fly ash, all samples achieve higher hardness readings as compared with pure epoxy.

Specimen No	Vickers micro hardness number
0% CGF + FA	11.81
0.5% CGF + FA	20.93
1% CGF + FA	24.75
1.5% CGF + FA	21.35
2% CGF + FA	23.31

Table 5: Vickers micro hardness test results

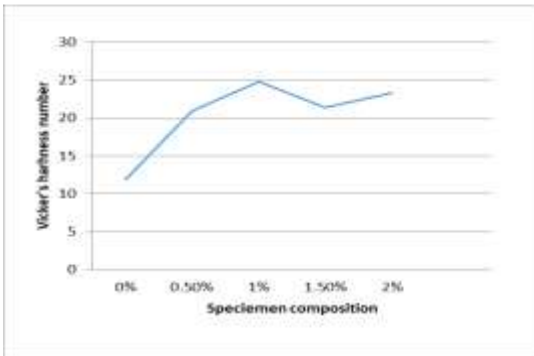


Figure 3: Vickers's hardness number vs specimen composition

From table we can find that the VHN is more for 1% specimen, which specifies that it is hard compared to other specimen. There is a % increase of 1.77% for 0.5% Specimen , 2% for 1% specimen and a decrease of 1.8% for 1.5% specimen , and 1.9% for the 2% specimen. This imply that mechanical properties of epoxy/chopped glass fiber with fly ash would be dropped if the amount of flyash excess their optimal value.

3. CONCLUSIONS

In this present study, the scope and objective of the studies have been fulfilled where the vibrational and mechanical characteristics of epoxy with different percentage of CGF+FA were tested experimentally and the results are compared and found to be in good agreement.

From the experimental modal analysis, the vibrational characteristics such as mode shapes, frequency and damping ratio were found.

1. From the result, we found that as the percentage of CGF + FA is increased the frequency also increased. The sample with 2% CGF +FA has the highest frequency which is 17.69 Hz to 218.7 Hz compared to other composition .Higher the frequency higher is the stiffness and life. Hence we can

conclude that 2% CGF + FA sample is better compared to other samples.

2. The tensile strength of the 0.5% CGF+FA sample found to be 19.67 MPa, which is higher than remaining samples. This shows that there is uniform distribution of CGF within epoxy and also good bonding between matrix and filler material.

3. From the results, we found that 1% CGF+FA has the VHN as 24.75.The hardness of the material depends on the amount of fly ash present. Fig 6.5 shows the indentation of 1% CGF + FA in which the fly ash particle resist the applied load. Hence we can conclude that 1% CGF+ FA sample is harder.

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