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Experimental Investigation on the Modal Response of FRP Composites

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Abstract: ***Estimating damping in structure composed of different materials (carbon, Kevlar fibres) and processes still remains as one of the most extreme vast challengers. The paper presents the structural damping effect on beam vibration by impact hammer. Structural damping contributes to about 0.3 – 0.5% of total system damping. The main objective of this work is to determine the natural frequency and damping ratio of cantilever beams of carbon and Kevlar fibres by M+P international SO Analyser and validate the result with the MAT LAB code written. Free vibration analysis was carried out for identifying the natural frequencies. The damping ratios are identified by using the same FFT where it uses half – Power Band Width Method as a source in the system. It is observed that the damping ratio is higher for Kevlar than carbon fibre reinforced composites.***

Keywords: Structural Damping, half – power band width method, M+P international SO analyser

1. Introduction

The concept of damping within a structural system can have different meanings to the various trade branches. Damping is one of many different methods that have been proposed for allowing a structure to achieve optimal performance when it is subjected to seismic, wind storm and other types of transient shock and vibration disturbances Fourier series can decompose any periodic signal or function into the sum of simple goniometric functions, namely function sinus and cosines. This decomposition of a complex function to set of simple function is the main advantage of the Fourier method [1]. The main reason for using the FFT in mechanical engineering science is to transform some time-domain digital signal into the frequency-domain signal. This approach is very useful for determining modal parameters of vibrating systems. If the vibrating system generates noise during its vibration, it is possible to record noise to the digital wave file and use the data for further processing. This paper describes some of the basics of FFT and discusses an example how Eigen frequencies of noisy vibrating system can be recorded to a digital sound file. Fourier experimentation was performed using software M+P international SO analyser. The results are compared with the other ones, received using the MATLAB program.

2. Experimental Procedure

The unidirectional carbon and Kevlar fibres of 240 GSM supplied by ARROW TECHNICAL TEXTILES Pvt.Ltd, India are used as a reinforcing material as shown in below figure 1.1, 1.2. The fibres are then mixed with epoxy resin chemically belonging to epoxide family used as matrix material (chemical description as Bisphenol A Diglycidyl Ether). The low temperature curing epoxy resin (LY 556) and corresponding hardener (AR 951) are mixed in the ratio of 10:1by weight ratio as recommended. The epoxy resin and corresponding hardener are supplied by Sree Industrial Composites ltd, Hyderabad. Carbon, Kevlar fibres and resin has Young's modulus of 125, 70.5, 3 GPa and possess densities of 1700, 1300, 1100 kg/m^3. The ratio between the fibre and matrix is 40:60. The composites are fabricated by hand lay – up technique. After applying this method, these composites were cured for 24 hrs at room temperature. Then, the composites were cut into size of $300 \times 200 \times 30mm$, according to ASTM E756. The pictures of the test specimens are presented in the below figure.

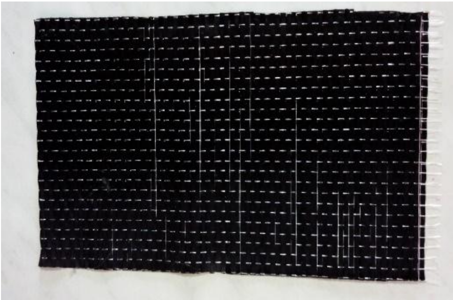

Figure 1.1: Carbon Unidirectional mat

Figure 1.2: Kevlar Unidirectional mat

Figure 1.3: Carbon Unidirectional Composite Plate

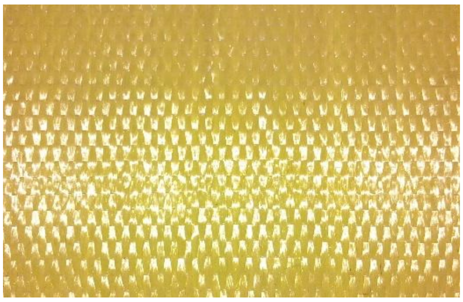

Figure 1.4: Kevlar Unidirectional Composite Plate

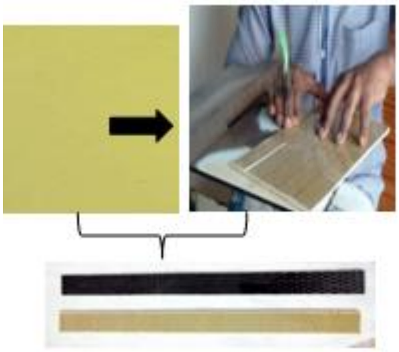

Figure 1.5: Specimens cut on Design Cutting Machine

Vibration of Composite Beam

On a structure, dynamic loading can vary from recurring cyclic loading of the same repeated magnitude, such as unbalanced motor which is turning as a specified number of revolutions. Here in this technique, the time domain is converted to frequency domain signal for each process using the Fourier transform. FFT uses half – Power band width method in its software. Where half – power band width method is also based on the magnitude of frequency – response function. Band width is defined as the width of frequency response magnitude curve when the magnitude is $\frac{1}{\sqrt{2}}$ times the peak value. Frequency response function (FRF) is the quantitative measure of the output spectrum of a system in response to a stimuli (disturbance). It is used to characterize the dynamics of the system. The software here used uses FRF as a main function.Here in this process of finding the dynamic characteristics of the composite material we use a standard equipment and software named M+P International SO Analyser. It is shown below.

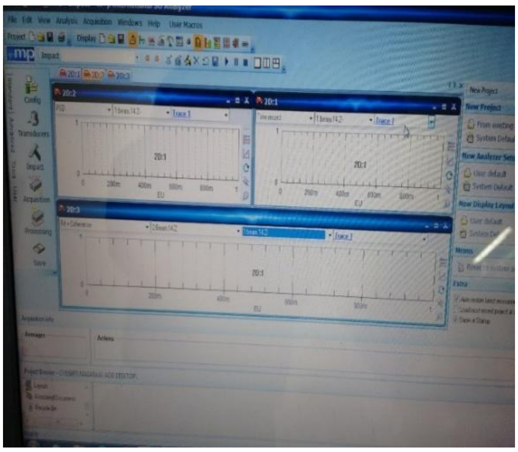

Figure 1.6: M+P International SO Analyser

The FFT equipment is shown in figure 1.7 where the sample is loaded using the G – clamp. The sample is loaded on the table using the clamp. Make sure that the sample is held properly so that we get the natural frequencies without any other disturbances that is coherence. Natural frequency is based on the Modal Assurance Criteria (MAC).

Figure 1.7: Specimen attached to G – Clamp

In this FFT, we do the modal analysis of the composite beam. The natural frequency varies based on three parameters.

a) Boundary Conditions (Fixed, Cantilever etc.)
b) Material Properties (Young's Modulus, Density, Poison's Ratio)
c) Geometric Parameters (Length, Breadth, Width)

Free Vibration

The samples 300mm x 25mm were cut out from the laminated composite plate. The specimens clamped in the steel stand in the form of cantilever beam with 100 mm span. The accelerometer (PCB 352C41) was glued to the tip of the specimen to measure the tip displacement.

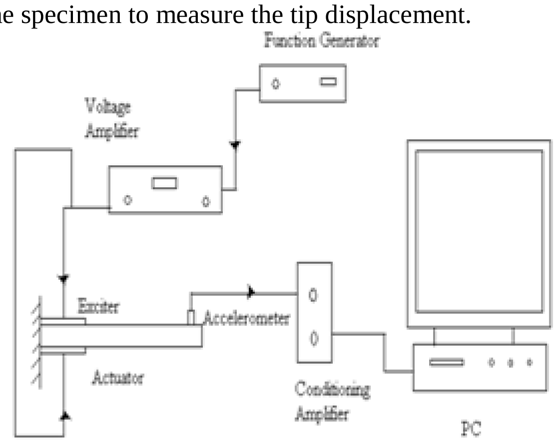

Figure 1.8: Shows the schematic illustration of experimental setup for vibration testing

M+P Analyser makes it simple to create a model of the structure's geometry and animate its mode shapes and shapes in general. The geometry editor allows intuitive creation of geometry models. Substructures, nodes, connecting lines and triangles can be entered by keyboard, pasted from a spreadsheet or imported from CAD programs via STL file format.

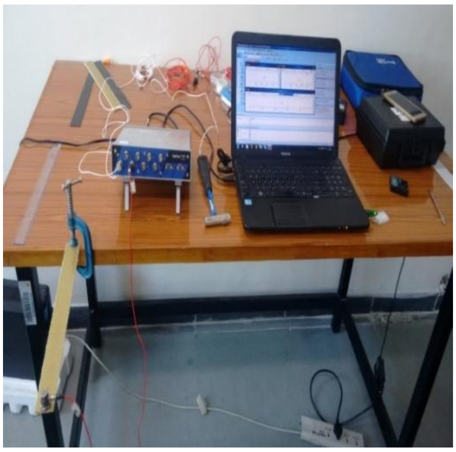

Figure 1.9: Final test setup of the equipment

Sample Rate

When determining the sample rate, it is necessary to choose a sampling rate which will prove a sufficient number of points per wave. It is important to note that a minimum of 2 points per wave is required to recreate the data graphically. Thus it was determined that 10 points per wave would be sufficient. As it turns out that the smallest sample rate available in audacity is 8000 points per second, it was chosen, and it happens to provide a greater number of points than 10 per wave, thus it was deemed sufficient.

3. Results and Discussions

Damping factor of CFRP and KFRP laminated composites are calculated to first four modes and the values in percentage for CFRP, KFRP laminates are given in Table 10.1, 10.2. It is observed that the damping factor of Kevlar fibres shows different values for the three different modes and also there is very high trend in the change of damping factor. The natural frequencies, damping factor and mode shapes were experimentally determined for four specimens. The four specimens are as follows.

CFRP Plate $0^0+0^0+0^0+0^0$
C+ C+ C+ C

KFRP Plate $0^0+0^0+0^0+0^0$
K+ K+ K+ K

Table 1.1: Vibration Properties of CFRP Plate $0^0+0^0+0^0+0^0$

Name	Frequency (HZ)	Damping (%)	Method	Type
Mode 1	9.375	3.97	Finite Difference	Structural
Mode 2	96.875	0.79	Finite Difference	Structural
Mode 3	140.63	4.31	Finite Difference	Structural
Mode 4	287.5	0.00	Finite Difference	Structural

Table 1.2: Vibration Properties of KFRP Plate $0^0+0^0+0^0+0^0$

Name	Frequency (HZ)	Damping (%)	Method	Type
Mode 1	14.063	2.84	Finite Difference	Structural
Mode 2	114.06	1.36	Finite Difference	Structural
Mode 3	142.02	5.14	Finite Difference	Structural
Mode 4	348.44	1.04	Finite Difference	Structural

The natural frequencies for the polymer composites of carbon/epoxy and Kevlar/epoxy are found experimentally. The carbon epoxy composite is showing its natural frequency values as 9.375, 96.875, 140.63, 287.5 Hz for different modes of vibration. The Kevlar epoxy composite is showing the natural frequency values as 14.06, 114.06, 142.02, 348.44 Hz for different modes of vibration. By averaging the natural frequency values of carbon and Kevlar, carbon 133.59 Hz and Kevlar exhibiting 154.64 Hz. This is because Kevlar acting as a ductile material, it has more natural frequency compared to carbon. The deflections of the composite beams i.e. modes of vibrations are obtained from the FFT analyser shown below.

The carbon epoxy composites showing its damping values as 3.97, 0.79, 4.31, 0.00 % and Kevlar epoxy composites showing its damping values as 2.84, 1.36, 5.14, and 1.04 %. By taking the average values of damping for carbon and Kevlar, carbon exhibits 2.26 % whereas Kevlar exhibits 2.59%. From this, it is seen that if stiffness increases, the natural frequency also increases and if the mass increases, the natural frequency decreases. And the natural frequency is little lower for carbon as it depends on the amount of damping. The level of vibration depends on the strength of energy source as well as the absorption or damping inherent in the system. Here the natural frequencies are based on the geometry modal that we created in the m + p international SO analyser software.

Here I have written a mat lab code for comparing the natural frequencies for the two plates using the material properties, geometric parameters and taking some constant values from an ASTM Standards. The natural frequencies that got from the mat lab code (Numerically) are compared with the experimental values. The mode shapes for the four specimens are as follows.

Mode Shapes

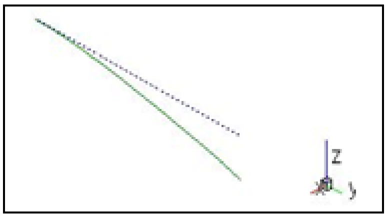

Figure 2: Mode 1

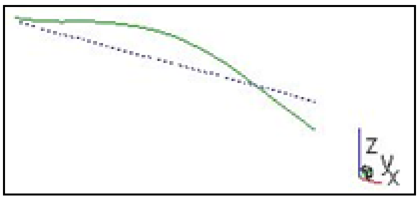

Figure 2.1: Mode 2

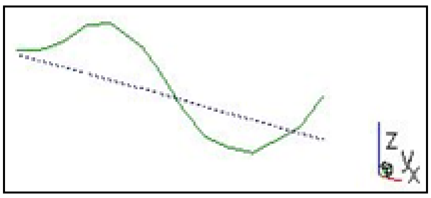

Figure 2.2: Mode 3

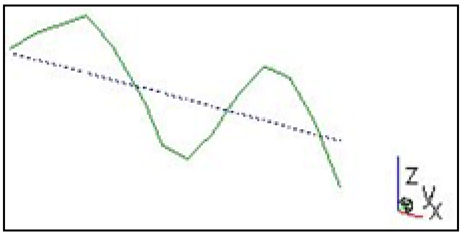

Figure 2.3: Mode 4

A mode shape is a specific pattern of vibration executed by a mechanical system at a specific frequency. Different mode shapes will be associated with different frequencies. The experimental technique of modal analysis discovers these mode shapes and the frequencies.

4. Conclusions

While comparing the natural frequencies of carbon and Kevlar fibre reinforced epoxy, Kevlar shows 15% improvement than carbon. The damping of Kevlar shows 0.36% higher than that of carbon. It is concluded that Kevlar is best suitable than carbon for the vibrational structures due to its organic and ductile nature.

5. Acknowledgement

I acknowledge Vibrations & Acoustics laboratory at IIT Hyderabad for providing lab facilities for conducting few experiments.

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