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Investigation of Modal parameters of Carbon & Kevlar Fiber composite Laminates using FFT Analyzer

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Abstract* — Composite Materials are known for their excellent combinations of High Structural Stiffness & Low Weight. They allow the Design Engineer to tailor the material in order to achieve the desired performance requirements because of their anisotropic properties. Therefore, it has become very necessary for Engineers to develop tools which allow the Design Engineer to obtain Optimized designs considering the structural requirements. Based on these requirements, this work considers the Dynamic behavior of Components manufactured from Fiber-reinforced Composite Materials. Towards this, Specimens of Carbon & Kevlar fibers were manufactured using the Hand Lay-up process followed by cutting to the required dimension. Experimental Dynamic Tests were carried out using specimens of different thickness. From the results obtained, the influence of the fiber orientations as well as the stacking sequences on the modal parameters like Natural frequency, Damping etc., were investigated. Also, Validation of the results of Theoretical and from the FEA was done. Good Agreement was obtained between the finite – element predictions and experimentalresults.

Index Terms— ***Composite Materials, FEA, Modal Analysis, Fibers.***

I. INTRODUCTION

Polymer Matrix composites are considered as the workhorse of the Composites Industry. They are commonly used in weight sensitive structures due to their high stiffness-to-weight ratios. They are especially significant in aircraft, aerospace and military applications. On the other hand, Polymers have temperature dependent mechanical properties. If dynamic stability and positioning accuracy are design requirements in polymer matrix composite structures, their damping properties must be investigated under varied temperature for possible use in different seasons, climates and regions.

PMC's have excellent room temperature properties at a low cost. They have been in use for about four decades. The matrix consists of various thermosetting resins and more recently, thermoplastic polymers reinforced by glass, carbon, boron or organic fibers.

Traditionally they were used in secondary load bearing aerospace structures. Now, they are used in I-beams in civil structures, various automotive parts, steel belted tires and in sports goods such as fishing poles, tennis rackets, golf clubs and skis. The cost of these materials has been steadily decreasing, which makes them economical enough for use in consumer goods. By definition, Composite is a material composed of two or more distinct components. Composites are divided into two categories: composite materials and composite structures. Composite materials are composed of reinforcing structures surrounded by continuous matrix whereas composite structures display discontinuous matrix.

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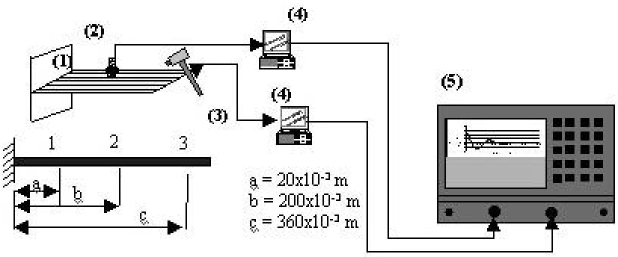
II. EXPERIMENTAL SET-UP

The following equipment shown in fig. below was used to perform an impact test:

1. 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 and direction.
3. A 4 Channel FFT Analyzer to compute FRF's.
4. Post-processing Modal software for identifying modal parameters and displaying the mode shapes in animation.



III. FFT ANALYZER

Frequency response function is a fundamental measurement that isolated the inherent dynamic properties of mechanical structures. FRF is an algorithm for calculating Digital FT in a fast and efficient manner using digital computers. 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. With the ability to compute FRF measurements in an FFT analyzer, Impact testing was developed and has become the most popular modal testing method used today.

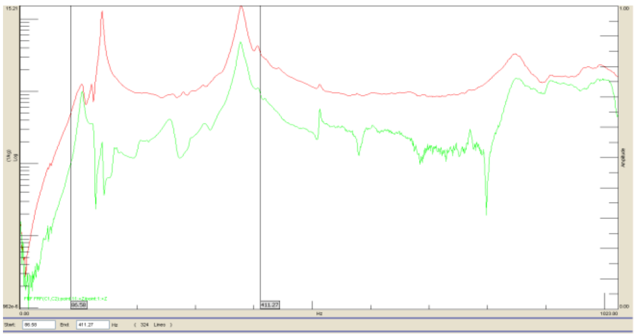


Fig – 2 Carbon – Cantilever condition

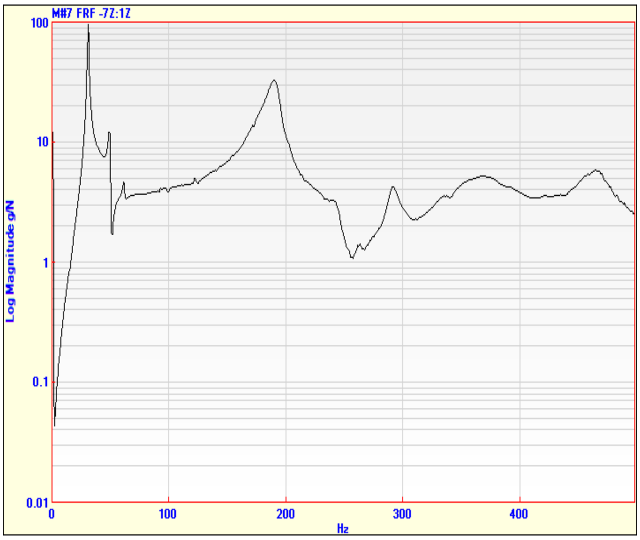


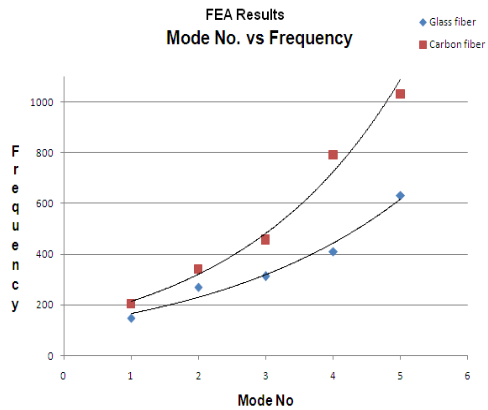
Fig – 3 Kevlar- cantilever condition

Carbon

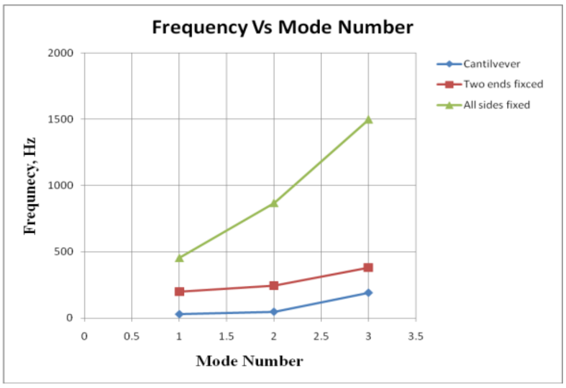
E_1 = 172.7 GPa
$E_2 = E_3$ = 7.2 GPa
$G_{12} = G_{13} = G_{23}$ = 3.76 GPa
$_{12} = \nu_{23} = \nu_{13}$ = 0.3

Kevlar

E1 = 112.4 GPa
E2 = E3 = 3 GPa
G12 = G13 = G23 = 8 GPa
12 = ν23 = ν13 = 0.26



Graph of carbon fiber



Graph of Kevlar fiber

Sl. No	Details of specimen	Boundary conditions
1.	Carbon Fiber specimen with 2 mm thickness	One – End constrained
2.		Both ends constrained
3.	Carbon Fiber specimen with 4 mm thickness	One – End constrained
4.		Both ends constrained
5.	Kevlar Fiber specimen with 2 mm thickness	One – End constrained
6.		Both ends constrained

IV RESULTS AND DISCUSSIONS

Both FEA and experimental results are found to be in good agreement.

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- As the mode no. is increased, there is a considerable increasing in the frequencies for both glass and carbon fiber composite specimens, however, the frequency values increase in case of carbon fibers, which indicates that carbon fiber specimens are much stiffer than glass fiber, this is also in accordance with the theory of vibration that higher the stiffness, higher the frequency of vibration.
- The graph of FEA results of mode no. vs frequency for both carbon and glass fiber, there is a definite increasing trend in the graph as explained in the above step.
- Shell 91 elements were used for modeling and meshing of the specimens and cantilever boundary conditions were simulated.
- Fig - 3 depicts the experimental modal analysis results of both specimens. The peaks in the graph indicates the frequencies of the specimens.

V. CONCLUSIONS

In this work, Experimental and Finite Element Modal analysis of polymer based composites have been considered for different types of fibers with various boundary conditions and the results are compared and found to be in good agreement.

- ✓ Experimental Modal Testing have been carried out using 8-channel FFT analyzer on various FRP based laminated composites with different boundary conditions.
- ✓ Finite element modal analysis on different composite specimens were carried out successfully and found to be in good agreement with the experimental results
- ✓ Four types of natural modes, namely flexural bending, torsional, in-phase and anti-phase waves and through-the-thickness modes, exist for freely vibrating panels irrespective of their boundary conditions. Generally, the frequencies of longitudinal and thickness modes are less sensitive to the boundary conditions.
- ✓ The Eigen frequency of the lowest flexural-bending mode significantly increases with the increase when both edges of the specimens are clamped. When they are clamped at only one end (Cantilever), the frequency of the bending mode somewhat decreases. Such a behavior completely complies with the known behavior of the homogeneous panels. At the same time, the Eigen frequencies of higher order modes increase slightly with the carbon fiber.
- ✓ We conclude that the SHELL 91 element for meshing the composite specimens yielded results with good accuracy. Hence, we recommend the use of SHELL 91 for dynamic analysis of composite specimens.
- ✓ The simplicity of the design too, seems to have played a vital role in obtaining good results between kevlar and carbon fiber. Finally the carbon fibers specimens seem to improve their dynamic performance without much sacrificing their weight.
- ✓ Also the results show that Kevlar has a very good damping thus making it very suitable in various industrial applications.

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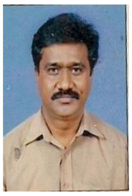

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