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Estimation of Dynamic Characteristics of a honeycomb Hybrid Composite Material

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***Abstract*—An important problem now a day'sfacing by design engineers in the aerospace industry is how to achieve better design concepts by considering manufacturing cost and structure performance in the early stages in developing a product. And the most important considerations in designing a spacecraft areweight. By reducing the weight of a spacecraft, it is easy to increase the payload, which reduces the launch cost and improves the power of moving quicker and easier, the structural and mechanical parts of a spacecraft generally represent a large percentage of its weight and, therefore, it is important to choose the better material and structural configurations to minimize the weight, one of the most important design criteria in many industrial applications is to reduce the weight of a structure without changing its strength and stiffness. And the search of the best quality and cost performance, for space vehicles becomes a complex process. The purpose of this work is to perform a modal analysis on honeycomb panels used in the aircrafts and satellites structural design. To fabricate the sandwich honeycomb panel, Jute fiber sandwiched between the Glass fibers are used as face sheets and Glass fiber as core material, Epoxy as a bonding agent. The developed honeycomb panel is subjected to dynamic investigations to determine the natural frequencies, damping factor and damping ratio based on clamped-free (C-F-F-F) boundary conditions. The obtained results show a good experimental test results**

Keywords— Honeycomb structure, American Society for Testing and Materials (ASTM), Fast Fourier Transform (FFT)

I. INTRODUCTION

Composite material is a combination of two or more materials in which one of the materials is called the reinforcing which is in the form of fibers, particles orsheets, and is embedded in the other materials called the matrix. The reinforcing material and the matrix material can be polymer, ceramic, or metal. Composites typically have a particle or fiber phase that is stronger and stiffer than the continuous matrix phase and act as the principal load carrying members. The matrix then acts as a load transfer medium between fibers, and in less ideal cases where the loads are complex, the matrix may even have to bear loads transverse to the fiber axis. The matrix is more ductile than the fibers and thus acts as a source of composite toughness. The matrix also serves to protect the fibers from environmental damage before and after composite processing. When designed properly, the new combined material exhibits good strength than would each individual material. Composites are used not only for their structural properties, but also for thermal, tribological, environmental and electrical applications.

II. PROBLEM DEFINATION

A. objective

the objective of present work is focused on fabrication of honeycomb sandwich structure for is subjected to dynamic loading and to investigate natural frequencies, damping factor and damping ratio based on clamped-free (C-F-F-F) boundary conditions. Initially the honeycomb is fabricated as core for sandwich structure then GFRP face sheets were fabricated as per ASTM standard.

B. Specimen Preparations

procedure used for fabrication of sandwich structures, the face sheets of the sandwich panel were Jute fiber sandwiched between the Glass fibers are used as face sheets and Glass fiber as core material, Epoxy as a bonding agent. The face sheets with a thickness of 1 mm and a fiber volume ratio of 60%. The core used for the sandwich panel was glass fiber/epoxy and it was 4 mm thick. The sandwich panel was fabricated by bonding the cured face sheets to the core material with epoxy and polyester resin as adhesive at room temperature, the face sheets and core were bonded together.

C. Selected Material properties

Material	Density (ρ) kg/m3	Poisson's ratio (μ)	Youngs modulus (E) Gpa	Shear modulus (G) Gpa	Volume fraction (%)
Glass fibre (200gsm)	2500	0.29	24.69	11.33	60
Epoxy/Resin	1250	0.35	2.75	1.5	40

TABLE: 1 PROPERTIES OF GLASS FIBRE AND EPOXY

- *Fabrication of Glass Fiber Factsheets for Sandwich Structure*

Glass fiber of 200gsm is cut in to dimension of 300 × 300 mm and calculating number of ply required for 1 mm thickness. Volume fraction for fiber/resin of 60:40 was taken for GFRP preparation

- *Fabrication of Honeycomb Core for Sandwich Structure*

Glass fiber of 200gsm is prepared like face sheets (Jute fiber sandwiched between the Glass fibers) with 1 mmthickness and volume fraction for fiber/resin of 60:40 was taken for FRP preparation.

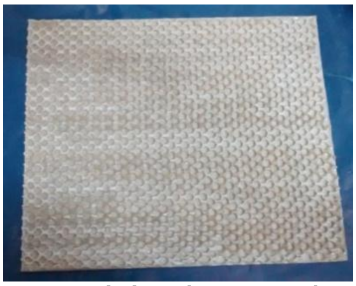

Fig.1: Prepared Glass Fiber Honeycomb Core

- *Honeycomb Sandwich Structure Preparation*

For the production of honeycomb sandwich structure, 1mm thick two glass fiber sheets and 10 mm thick one glass fiber honeycomb core are used of more than final required dimensions (300 × 300 mm). The components required for preparation of honeycomb sandwich structure is shown in below fig.2.

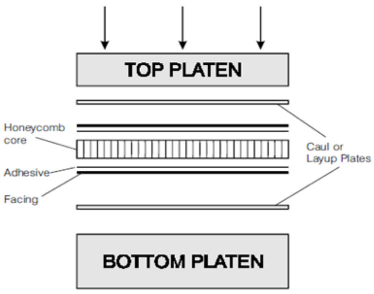

Fig.2. Components used for Preparation of Honeycomb Sandwich Structure

- *Procedure for Preparation of Honeycomb Sandwich Structure*

1. Placed the prepared polyester/epoxy face sheet during preparation of sandwich on ceramic tile.
2. Prepare Epoxy/resin of LY556 type and hardener of HY951 type mixture as adhesive with 10:1 ratio.
3. Resin and hardener were stirred for five minutes for uniform mixing.
4. Applied the require amount of adhesive (resin + hardener) and spread on a bottom face sheet and to one side of honeycomb core material using spreader.
5. Then placed the honeycomb (adhesive coated side) core on bottom face sheet and align in proper position.
6. Again applied the require amount of adhesive to top of honeycomb core and to the other face sheet.
7. Then placed the face sheet with adhesive downside on top side of honeycomb core and covered with two tile blocks for 24 hours.
8. Cut the sides of prepared sandwich shown in fig.3.4 to the required Standard dimensions of 300 × 300 mm with overall thickness of 6 mm.
9. Finally, the sharp edges are removed by using emery sheet in the honeycomb sandwich structure

Fig.3. Prepared Honeycomb Sandwich (Honeycomb Core between 2 Face sheets)

D. Specifications

- Final sandwich panel: Square Plate of 300 x 300mm
- overall thickness : 6 mm
- overall mass : 0.525 kg

E. Methodology

Free vibration takes place when a system oscillates under the action of forces inherent in the system itself due to initial disturbance and when the externally applied forces are absent. The system under free vibration will vibrate at one or more of its natural frequencies which are properties of the dynamical system established by its mass and stiffness distribution.

In actual practice there is always some damping (e.g., the internal molecular friction, viscous damping, aero-dynamical damping etc.) present in the system which cause the gradual dissipation of vibration energy and it result gradual decay of amplitude of the free vibration. Damping has very little effect on natural frequency of the system and hence the calculations for natural frequencies are generally made on the basis of no damping. Damping is of great importance in

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limiting the amplitude of oscillation at resonance. The block diagram of fast Fourier transform (FFT) shown in Fig 4

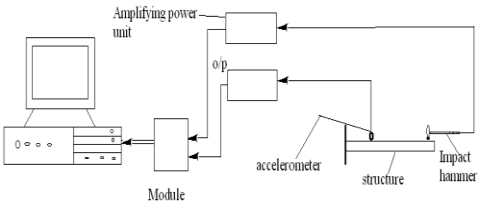

Fig.4Block Diagram of Experimental Setup for Modal Analysis

The relative displacement configuration of the vibrating system for a particular natural frequency is known as the mode shape (or Eigen function in continuous system). The mode shape corresponding to lowest natural frequency (i.e. the fundamental natural frequency) is called as the fundamental (the first) mode. The displacements at some points may be zero. These points are known as nodes. Generally nth mode has n-1 nodes (excluding end points). The mode shape changes for different boundary conditions of the beam.

In present work a cantilevered rectangular symmetric plate of glass fiber honeycomb sandwich composite with dimension 300×300×6 mm having aspect ratio of 0.8 with two face sheets of 1mm thickness each and core of 4 mm thickness.

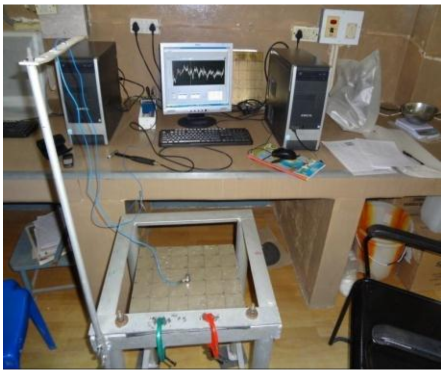

Fig.5 Experimental Setup for Modal Analysis

The experimental set up is as shown in Fig.5. A grid of 7×6 (42 points) measurement points were marked over the surface of the test specimen. The specimen was clamped on test fixture and an impulse technique was used to excite the structure by impact hammer with force transducer built in to the tip to register the force input. The excitation signal was feed to the analyzer through amplifier unit. A piezoelectric accelerometer stuck on the desired measuring point of the specimen senses the resulting vibration response. The accelerometer signals were conditioned in the charge amplifier and fed to the analyzer. The analyzer in conjunction with Fast Fourier Transform (FFT) gives mathematical relation between time and Frequency Response Spectrum (FRS) and coherence functions are registered in the selected frequency range. At each grid point five measurements were made and their average was obtained. The output data of all 42 measurements was used as an input data for LABVIEW-2009 package to identify response frequencies. From the response frequencies natural frequencies, damping factor and mode shapes were obtained and animated.

III. RESULTS AND DISCUSSION

Experimental Modal (FFT) Result Analysis

A cantilever test plates of honeycomb sandwich composite having dimensions 300×300×6mm were tested to obtain modal properties. The structural testing, analysis and reporting, LABVIEW-2009 software which uses frequency response function (FRF) method to identify the modal parameters of a structure is used. As explained, in this method, FRF measurements are made with an FFT analyzer and transferred to the lab view system for processing and curve fitting [18]. Table: 2 show the modal frequency and the damping factor of honeycomb sandwich plate.

Table: 2Experimental Modal Properties of Honeycomb Sandwich

Mode No.	Natural Frequency (fn) in Hz	Damping Factor (ξ) %
1	51.286	0.629
2	101.669	0.931
3	164.439	0.867
4	325.243	0.851

Fixed excitation is used here to obtain the response at various points on the specimen and results are also obtained at all points. In Magnitude–Frequency response graph the peak from left to right of Fig.6 shown below relates to corresponding mode shapes from 1 to 4 of honeycomb sandwich plate.

Fig.6Magnitude–Frequency Response of Honeycomb Sandwich

The mode shapes gives the information of dynamic behavior of plates under various natural frequencies. The mode-1 is called as fundamental mode in bending, mode-2 is in twisting and mode-3 is combination of bending and twisting. The first three experimental mode shapes obtained for honeycomb sandwich plate are as shown in fig.7, 8 and 9.

Mode: 1 (Bending)
Frequency: 51.286
Damping factor: 0.629%

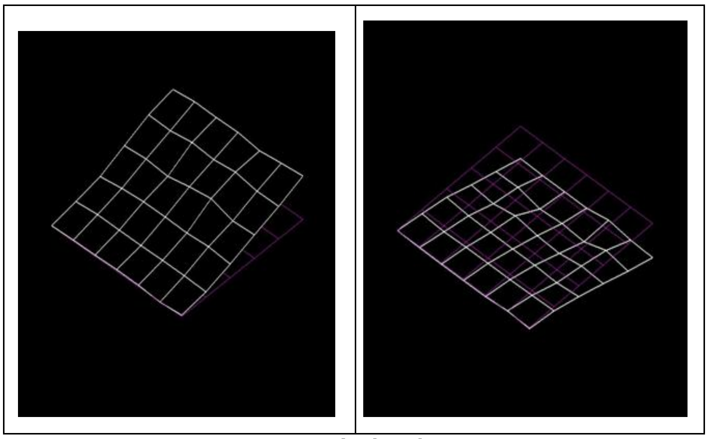

Fig.7:1st Mode Shape by FFT

Mode: 2 (Twisting)
Frequency: 101.669 Hz
Damping factor: 0.931%

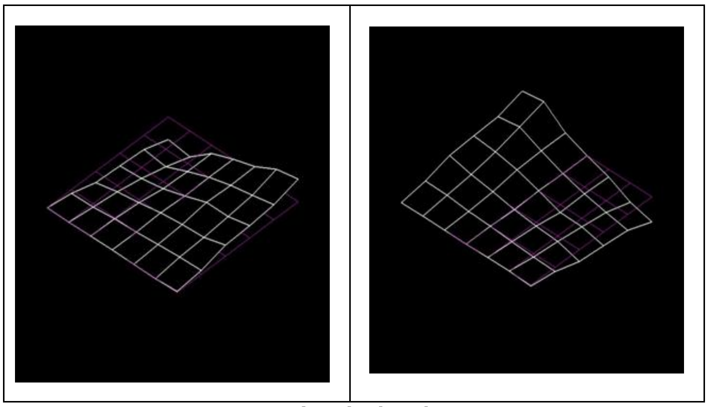

Fig.8: 2nd Mode Shape by FFT

Mode: 3 (Double bending)
Frequency: 164.439Hz
Damping factor: 0.867%

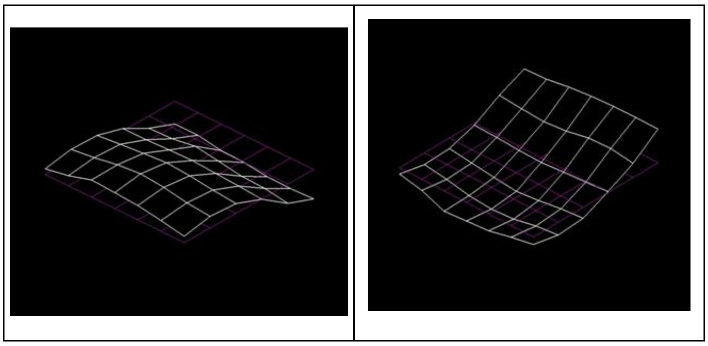

Fig.9: 3rd Mode Shape by FFT

Mode: 4 (Combination of bending & twisting)
Frequency: 325.243Hz
Damping factor: 0.851%

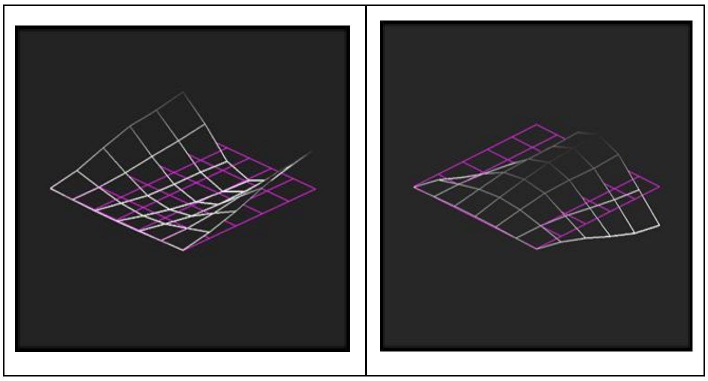

Fig.10: 4^{th} Shape by FFT

IV. CONCLUSION

In this study, the mechanical characterization of Glass fibre epoxy honeycomb sandwich structure as per ASTM standards is discussed.

- The ultimate tensile strength and Youngs modulus of developed honeycomb panel is 52.31MPa and 1511.85MPa respectively and which as good agreement with theoretical results.
- The flexural bending strength and flexural strain of developed honeycomb panel is 42.51 MPa and 0.0193 respectively and which as good agreement with theoretical results.
- Experimentally determined the natural frequency and mode shapes for honeycomb composite sandwich structure by using Fast Fourier Technique (FFT) analyzer is done by considering clamped free boundary conditions.
- The results of the model presented in this analysis is obtained with good accuracy which presents an efficient approach for aircrafts and satellite structures leading into the reduction of cost and time of analysis.

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