Vibration and Damping Behaviour of Bamboo/Epoxy Polyurethane Foam Sandwich Structures

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Abstract

This research was aimed at fabrication and characterisation of bamboo/epoxy polyurethane sandwich structures for vibration and damping behavior. Sandwich panels with polyurethane foam as core and bamboo/epoxy as facesheets were fabricated using vacuum infusion process. The specimens were characterized for modal and harmonic analyses using FFT analyser and DEWESOFT software. Natural frequency and critical damping increased significantly with increase in foam density. In-plane and out-of-plane vibration characteristics were studied. Fundamental frequency increased exponentially in post-flexural regime. Experimental load vs. deflection and natural frequencies agreed with finite element analysis results.

Keywords: *Sandwich structures, FFT Analyser, Natural frequency, Critical Damping, Finite Element Analysis*

1.0 Introduction

Sandwich structures are used in automotives, aircrafts, submarines, ships and boats, wind blades, etc. [1-3] as they have high strength and stiffness to weight ratios, superior fatigue and thermal properties. If a system vibrates with a frequency equal to that of eigen-frequency of the body, resonance occurs which can cause drastic failure. Damping of a body has the effect of reducing the vibrations in a body. The damping factor describes how the vibrations decay after a period of time. Hence, the vibration and damping analysis of a body is important.

The natural fibre based sandwich structures show good performance under dynamic conditions. Pankaj Charan Jena [4] made samples of different bamboo weight content and conducted mechanical tests. Natural frequencies were seen to increase with the weight content of bamboo. Rajesha et al. [5] studied natural frequency and damping factor of banana and sisal fibres based hybrid composite beam with polyester skins. Fibres are treated with sodium hydroxide. Natural frequency increases initially with increase in fibre content and it decreases for higher fibre loading. [6]. Senthilkumar et al. [7] conducted mechanical and dynamic investigations of composites made from pineapple leaf fibres by studying the influence of the fibre content (25, 35 and 45%) on the properties of

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the structures. It was observed that the natural frequency increased with fibre content. Chethan et al [8] used urea sheath fibres and epoxy resin. Poly vinyl carbon powder was used as a releasing agent. Rachchh and Trivedi [9] studied mechanical parameters and performed vibration analysis of hybrid sandwich type composite plates made from e-glass / bagasse and polyester resin. It was observed that 9 % bagasse fibre plate showed best vibration and mechanical performance. Vitale et al. [10] studied fibre reinforced honeycomb cores using Vacuum Assisted Resin Transfer Molding with combination of natural fibre cores, PVC foam core and jute reinforced glass fibre skins. Vaswani et al. [11] conducted studies on curved sandwich beam with visco-elastic core (aluminum skin and PVC foam core). Kushwaha et al.[12] conducted experiments on natural fibres such as bamboo, basalt, cotton, flax, hemp, jute, henequen, ramie, sisal, pineapple leaf, kenal, lyocell and wheat straw pulp with different resin types to calculate their interfacial shear strength. Hydrophilic fibre and hydrophobic matrix undergo debonding easily under loading conditions. The objective of the research was to fabricate sandwich structures using bamboo/epoxy as skin and polyurethane foam as core and to conduct vibration analysis on the beam specimens experimentally and using FEM.

2.0 Methodology Adopted

2.1 Surface treatment of fibers

Bamboo fibres were treated using 5% NaOH. Pellets of NaOH were dissolved in water (Fig. 1) and NaOH: fibre in 13:1 wt.% was used. The fibres were soaked for a specific period of time and dried.

2.2 Sandwich Manufacturing

The foam core was cut from a block of foam, having dimensions of 250 x 50 x 8 mm^3. The density of the polyurethane foam used is 70 kg/m^3. Epoxy LY5052 and hardener HY951 (10:1). was applied and bamboo fibres were layed up. The process was repeated for the second layer. Vacuum bagging technique was used to fabricate the specimens. Beams of 250 x 50 x 12 mm^3 were obtained as shown in Fig. 2.

Fig. 2. Beam made with Bamboo epoxy skin and PU foam core

2.3 Vibration Testing

Fast Fourier Transforms (FFT) using DEWESOFT was used for the experimental study. The setup involves the use of an impact Hammer, Accelerometer and an 8 – Channel FFT Analyser. Testing was performed in free-free boundary condition by placing the beam on two low density sponges. Two sets of results for in-plane and out-of-plane vibrations were obtained by placing the accelerometer on the beam(Fig. 3 and 4).

The sandwich beam was marked with four lines for the hammer impact points. Following the test procedure the graph of amplitude and frequency was directly obtained from the software and half power bandwidth method was used to obtain damping factor at the respective points.

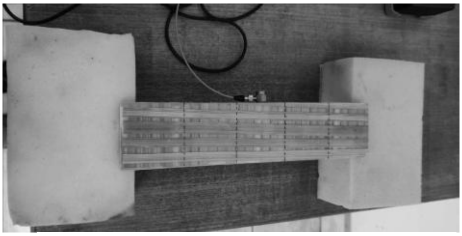

Fig. 3. Accelerometer: in-plane

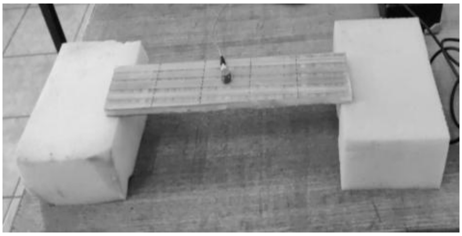

Fig. 4. Accelerometer: out-of-plane

3.0 Experimental Results

From amplitude vs frequency results (Fig. 5 and 6), the natural frequencies of the beam was obtained. The frequency range selected was 0 to 5 kHz. The out of plane vibration denotes that the accelerometer to be attached on the top side of the beam parallel to the ground. Natural frequencies are shown in Fig. 7. The peaks show that the amplitude is maximum at this point. Thus, the corresponding frequencies are the natural frequencies.

The damping factor at each of the peaks are found by first multiplying the peak amplitude by 0.707. The obtained value is then marked on the graph with a horizontal line. The curve meets this line at two points. These two points are then dropped down to find the frequencies f_1 and f_2. The experimental results are plotted Fig. 7 and 8.

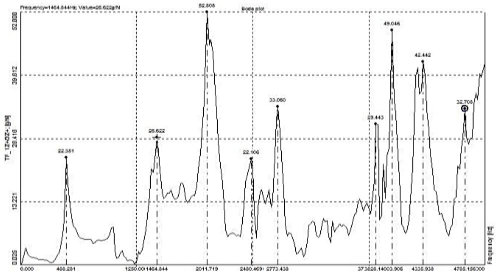

Fig. 5. Out-of-plane vibration Amplitude vs Frequency

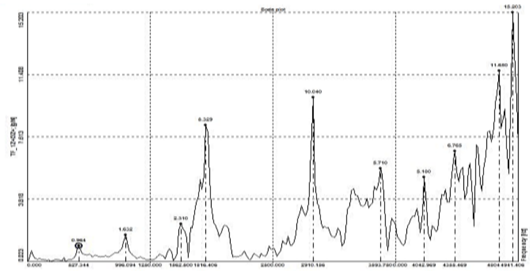

Fig. 6. In-plane vibration Amplitude vs Frequency

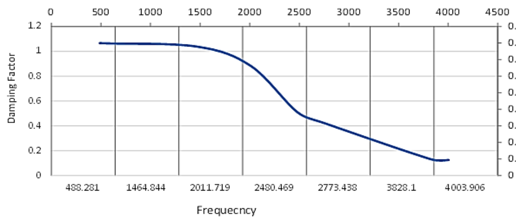

Fig. 7. Damping factor vs. frequency in out of plane vibration of bamboo sandwich structure

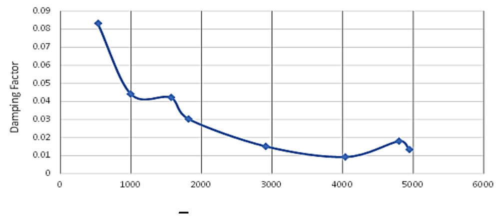

Fig. 8. Damping factor vs. frequency in plane vibration of bamboo sandwich structure

Fig. 9 shows that the three plots are not aligned. The natural frequencies increased with the curvature angle. Variation in natural frequencies in the three beam specimens is due to the change in stiffness of the beams. This pattern is more significant in the higher modes 34 to 50.

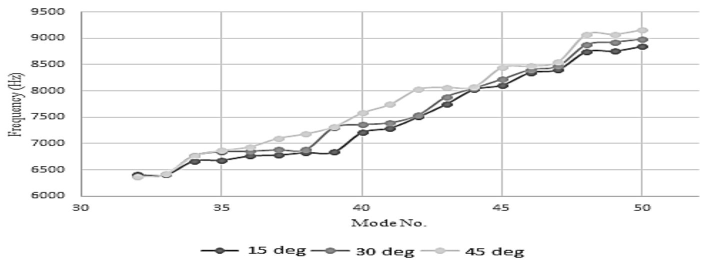

Fig. 9. Higher modes of vibration vs frequency

4.0 Conclusion

- A composite beam was manufactured with bamboo fibres and epoxy resin. The bamboo fibres were treated with 5% NaOH and dried which to enhance their physical properties.

- Vibration analysis was performed using DEWESOFT software with impact hammer method under free-free condition and two sets of results were obtained through in-plane and out-of- plane vibration. The results of in-plane natural frequencies match with that of the Finite Element Analysis.
- Damping factor was computed using half power bandwidth method. The damping factor reduced with increase in frequency.
- Vibration analysis on curved beams having end face angle as 15 degree, 30 degree and 45 degree show that there is a change in the natural frequencies when compared to each other. The natural frequencies tend to increase with curvature which is more significant in higher modes of vibration.

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