DYNAMIC RESPONSE OF CHEMICALLY GLUED NATURAL AND SYNTHETIC HYBRID COMPOSITES

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Abstract

In an effort to lessen vibration-related syndromes, a lightweight, stiff hybrid composite is being created, with potential applications in the design of acoustic buildings, hand-held instruments, lightweight constructions, and surgical tools. In order to reduce vibration, new hybrid materials are created. Dynamic testing is conducted on a hybrid composite made by hand layup that combines natural and synthetic fibres. Using the Fast Fourier Method, the eigenvalues, Eigen modes, and damping ratio are being calculated (FFT). When bonded with e-glass, it has been discovered that jute and hemp hybrid composites exhibit underdamped properties and attenuate vibration much more quickly than the other hybrid composites. Its damping ratio is also discovered to be less than one i.e., $\xi<1$. In vibration attenuation-related applications where quick structure-borne noise needs to be mitigated, this result validates the initial requirement. The two hybrid composites mentioned above were revealed to have the highest eigenvalue of 301.577 Hz. Designing, improving, and mitigating vibration-related syndrome in hybrid composite structures can be done using the results of the current study.

Keywords: Composite, Jute, Hemp, Basalt, Carbon, E-glass, Modal analysis, FFT,etc.

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1. Introduction

The risk of vibration and noise is posed by a variety of devices, including machinery, hand-held devices, medical devices, and other items [1]. When using composites in a service, it is important to fully understand their anisotropic properties and dynamic reactions. To obtain high stiffness, high tensile strength, and exceptional durability over the duration of their service lives, engineers must anchor and modify natural and synthetic fibres. Research on the use of both natural and synthetic fibres is ongoing. Since natural fibres are well known for their fire resistance, biodegradability, low weight, affordability, and ease of availability, they are frequently employed in fabric and aesthetic applications [2, 3]. Conversely, synthetic fibres offer excellent strength and elasticity and may be altered thanks to flexible production techniques [4]. It has long been a preferred choice for engineers and scientists. Many engineering projects, including those in the domains of aerospace, automotive, military, packaging, structural engineering, and medicine, have identified uses for synthetic fibres [5]. Jute has minimal heat conductivity, is antistatic, and blends well with synthetic fibres, yet it usually loses strength when wet, according to study[6]. The hydrothermal properties of hemp, on the other hand, are regarded to be excellent for resisting damage, being self-insulating, and being moisture-proof [7]. The current initiative aims to combine the benefits of natural and synthetic fibres. Due to the lack of research on the composite combination, there is still room for advancement and new findings.

According to research, rapid improvements in cutting-edge technology, such as the FFT analyzer and software technology have made data collection methods easier for the assessment of the dynamic behaviour of structures [8]. Engineers and scientists may now build structures that are more reliable and long-lasting. In engineering sciences, dynamic analysis is essential for determining the condition of a vibrating structure. Modal sensitivity analysis is one of the most popular subjects in the study of dynamic reactions nowadays since it has developed into an interdisciplinary technique. Understanding modal analysis enables engineers to reduce fluid-induced vibrations, noise, and vibration harnessing in addition to assisting them in the construction of towering buildings, dams, bridges, and space projects (NVH)[9]. Unique hybrid composites were made using the hand-layup technique [10] and then put through a dynamic examination.

In the current studies, a commercial natural fibre mat composed of jute and hemp is being layered on top of a synthetic mat consisting of basalt, carbon, and e-glass. Commercial natural fibre and synthetic mats were made using the hand-layup technique. Jute-Basalt (J+B), Jute-Carbon (J+C), Jute-Eglass (J+EG), and Hemp-Basalt (H+B), Hemp-Carbon (H+C), and Hemp-Eglass (H+EG) are the names and abbreviations given to the developed hybrid composites. Based on analyses of dynamic responses, including eigenvalues, eigenvectors, and damping ratio effects, a suitable hybrid composite candidate has been proposed.

2. Experimental Methodology

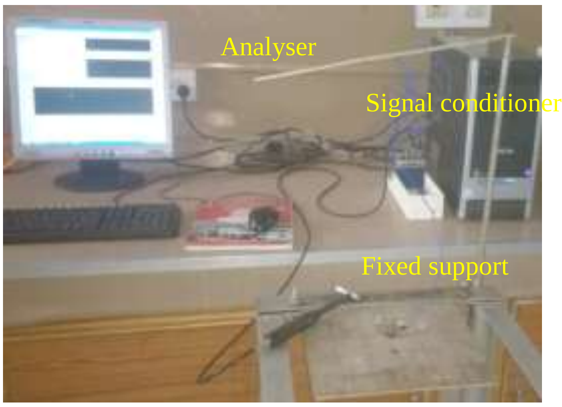
2.1. Fabrication technique

A hand layup technique was adopted to manufacture the hybrid laminated composites. For the dynamic test, the dimensions of the plates were kept at 350×250×6 mm. Initially, the mold was cleaned and coated with a release anti-adhesive agent, silica gel. The top surface of the mold is then formed by applying a resin coating. A layer of liquid resin matrix and reinforcement is laid layer by layer, and finally, the part is allowed to cure. Manual rollers were used and rolled over the layers to remove entrapped air pockets and a uniform thickness was maintained. A commercial epoxy resin-Lapox L 12 along with K6 hardener [11] was used in 10:1 ratio for superior curing results, refers to Fig 1(a) & (b). The technical specification of the epoxy Lapox L-12 resin are as follows: Modulus of Elasticity (MPa): 4400-4600±10%,FlexuralStrength(MPa):130-140±10%,ImpactStrength(KJ/m^2)17-20±10%,TensileStrength (MPa):50-60±10%, Compressive Strength (MPa):110-120±10%

Fig.1: (a) Lapox L 12-Resin and K-6 Hardener (b) Fabrication of hybrid composite using Hand Layup Technique.

2.2. Dynamic Test using FFT

The dynamic study was carried out in a laboratory environment. A free boundary condition was adopted to support the composite plate. The Fast Fourier Transform algorithm (FFTA) was used for the assessment of dynamic parameters[12]. Dynamic analysis was carried out to obtain dynamic responses, namely the frequency and mode shapes of the hybrid composite plates. The composite structure was isolated from the FFT analyzer. The experimental setup, along with important gadgets used in the analysis, was the piezoelectric impact hammer, transducer, signal conditioner, and analyzer refer to Fig.2 .The composite plate was divided into forty-one grid points, and these points provide an avenue for signal-to-noise ratio (S/N) identification [13]. The pulsating responses were recorded by a piezoelectric accelerometer at the desired measuring points until a significant S/N signal was obtained (refer to Fig. 3). A fixed excitation method was used to obtain the response at various grid points on the hybrid composite, and the data were transferred to the LabVIEW 2009 software[14] for further signal processing. Comparative dynamic analysis has been done on the hybrid composites J+B, J+C, and J+EG and H+B, H+C, and H+EG, and the results, viz., eigenvalues and effect of damping ratios (ξ), are compared.



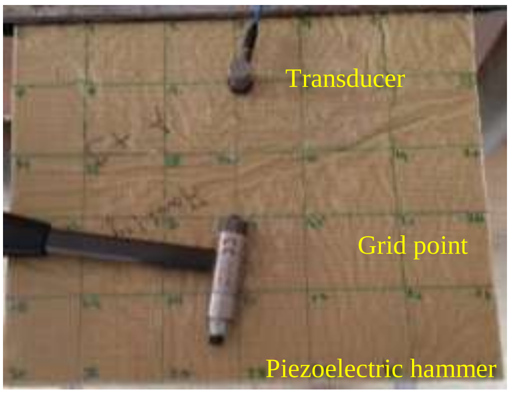


Fig.2: Shows the test rigs used in a dynamic analysis of a sample hybrid composite.

3. Results And Discussion

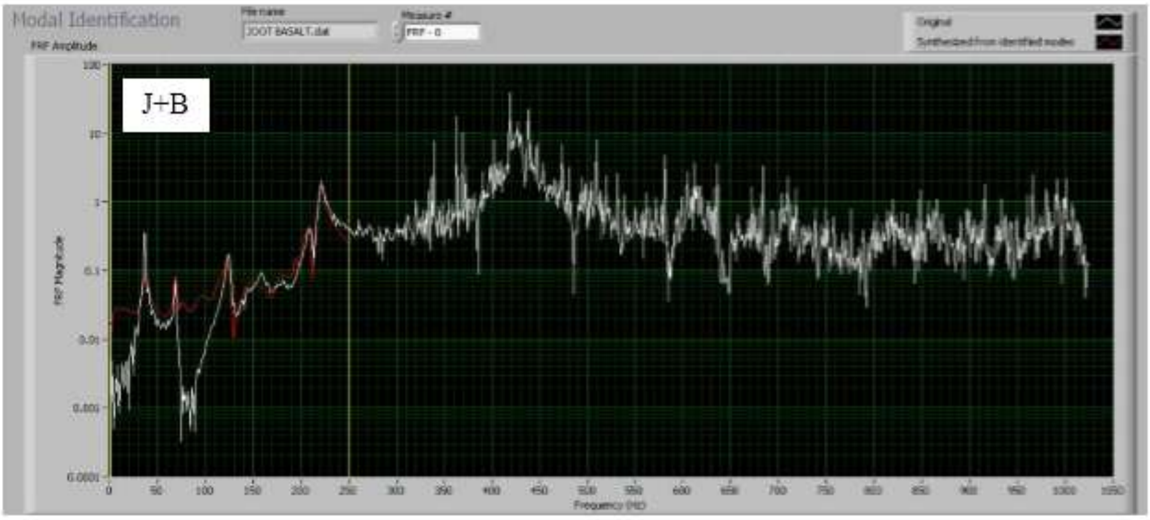
A Fast Fourier Transform (FFT) analyzer has been used to explore the dynamic examinations of eigenvalues, eigenvectors, and impacts of damping ratios in lumped systems/hybrid composites, namely J+B, J+C, and J+EG, and H+B, H+C, and H+EG. Figures 4(a) and 4(b) show the frequency response function vs. frequency spectrum graph for the aforementioned hybrid composites, which was collected from the instrument at one of the best measurement grid points. Table 3 displays the eigenvalues for the hybrid composites. The first five eigenvalues and their related modes have been recovered by a comparison study. It has been noted that, out of all the hybrid composites, jute blended with carbon (J+C) exhibits the greatest eigenvalue at 301.577 Hz and hemp blended with e-glass (H+EG) the lowest at 28.648 Hz. Tables 3 and 4 show nearly identical eigenvalues obtained when jute was combined with e-glass (J+EG). A high eigenvalue indicates low stiffness, while a low eigenvalue indicates high stiffness. According to prior studies, adding stiffener or mass significantly affects natural frequency [15] and can be customised to match particular needs. Eq. 1 illustrates mathematically free vibration for a lumped system, and Eigen values can be computed [16].

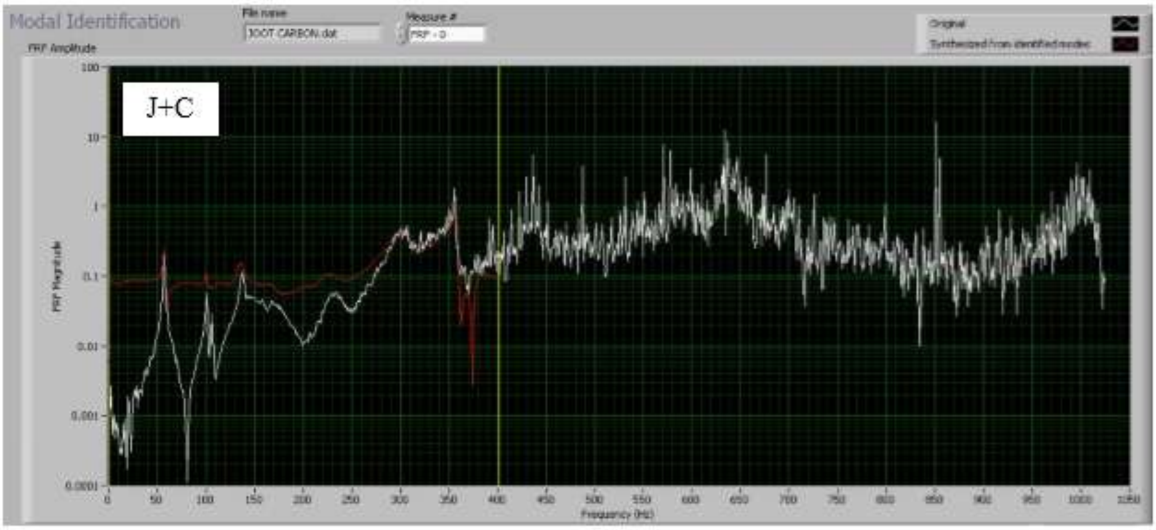
$$([K] - \boldsymbol{\omega}^2 [M]) \{d\} = \{0\} \quad \text{--------------------} (1)$$

Where M is mass, ω and {d} are Eigen values (natural frequencies) and the corresponding Eigen vector (mode shape) and displacement of the lumped systems.

For the hybrid composites, the impacts of damping ratios have been extracted. The dynamic decay of lumped systems over time was discovered by a damping ratio analysis. Early in the design process, designers can better grasp material modes by having a solid understanding of damping ratio. Because structural instability is indicated by a high damping ratio value, future design considerations must be made. The J+C hybrid system's damping ratio is relatively high and quite sensitive, with the highest natural frequency reported in comparison to other hybrid composites (refer Fig.5b). It has been noted that after a few oscillations, structures made of e-glass laminated with jute and hemp reach a stable state, making them suitable for use in the creation of structure born-noise and vibration harnessing (NVH) structures. H+EG hybrid composites had the least damping ratio, at 1.381%, when compared to H+B, H+C, and H+EG hybrid composites. Hence, the damping ratio magnitude expresses the rate of energy dissipation with respect to time of the amplitude of a vibrating structure. Because the magnitude is more than one, the structure can be regarded as meeting the overdamped criterion. The damping ratio (ξ) for the other hybrid composites was discovered to be less than 2.66%. However, the damping ratio (ξ) was discovered to be slightly greater and reported at 5.3% for J+B, J+C, and J+EG composites.

The modes shapes are no differences with variety of hybrid composite. The lab view software recorded the majority of the shape modes, which included twisting, bending, and combinations of twisting and bending [17]. Other mode shapes were found to be repeated and are of modest practical interest. The significant modes are addressed in the dynamic analysis. The mode shapes were extracted for all the composites and are categorised into three modes. The three reference mode shapes and eigenvectors that are within the specified natural frequencies/eigenvalues are shown in Fig.7.The reference mode shapes would provide the designer with an idea of the mode participation factor and the region of high stress, which could affect the fatigue life of the structure's deformation under dynamic loading conditions. The mode participation factor (MPF) is a measure of the contribution of a particular mode of vibration to the response of a structure. In composite structures, the MPF can be affected by various factors such as the fiber orientation, stacking sequence, and boundary conditions[18]. Therefore, it is important to carefully consider these factors when calculating the MPF. Overall, the MPF is a useful tool for understanding the dynamic behavior of composite structures, and can be used to optimize the design and performance of these structures in various applications.





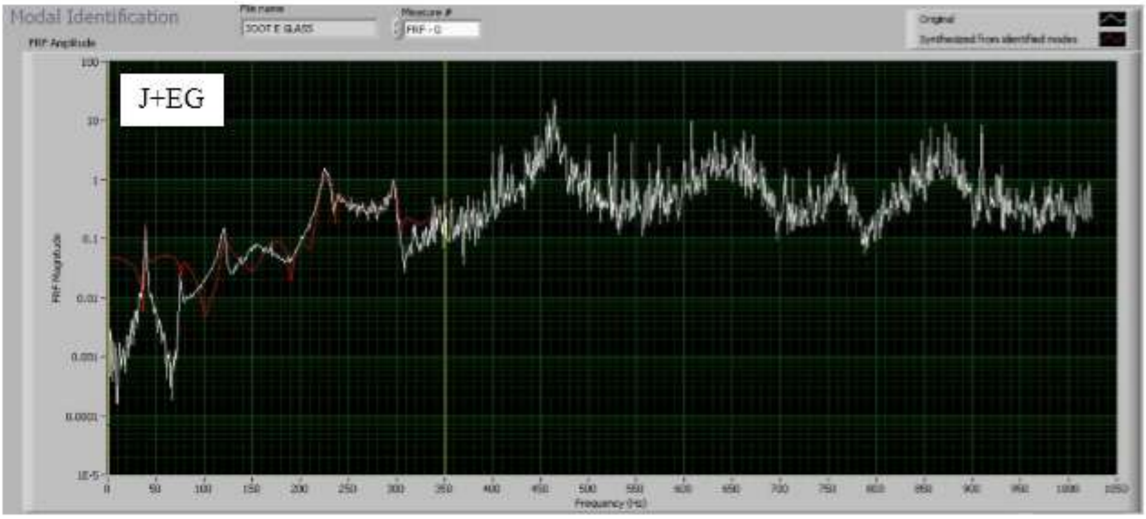
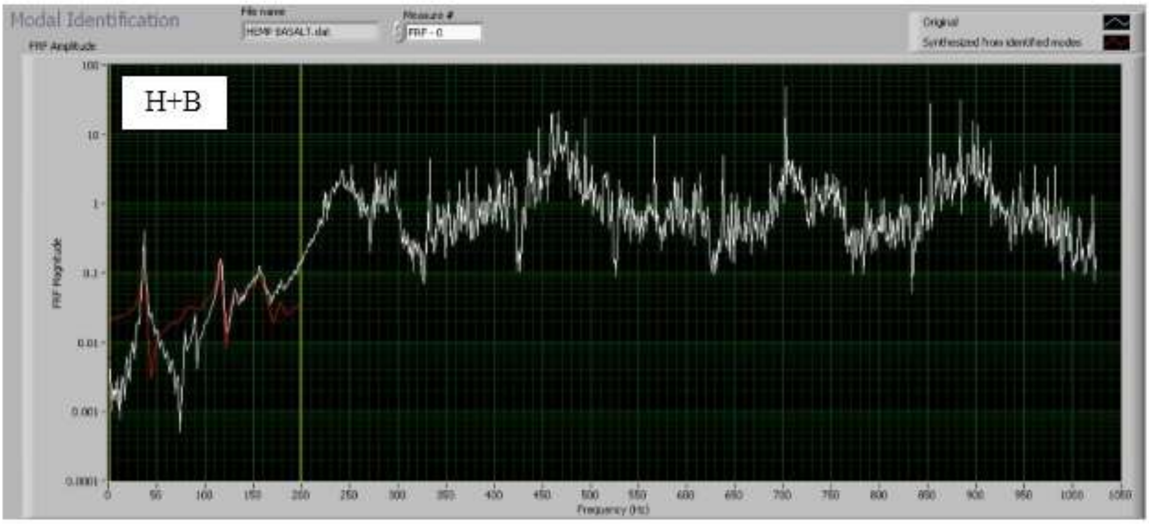
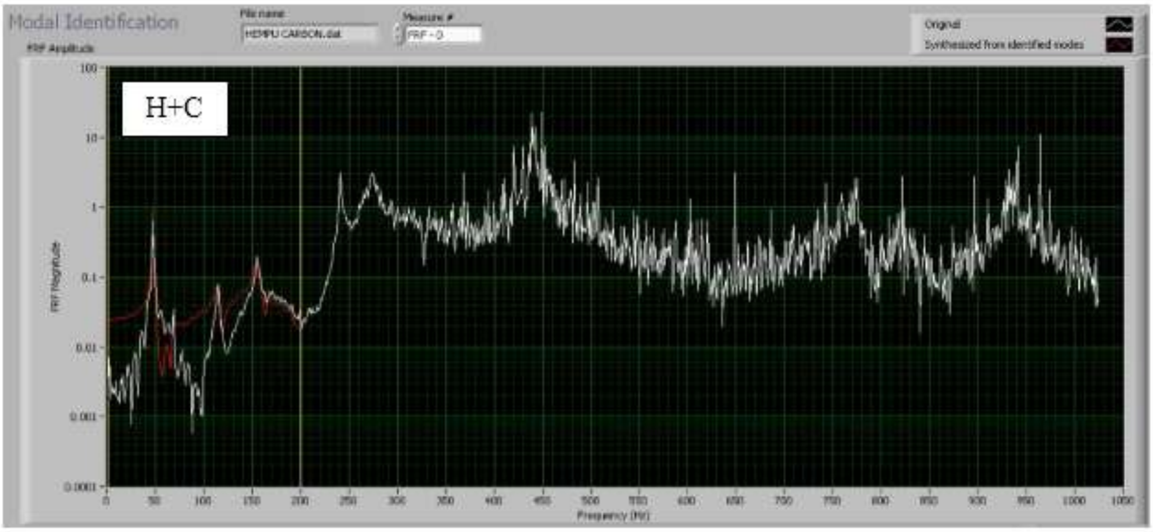


Fig.4(a): Frequency Response Function Versus Frequency spectrum of J+B,J+C ,and J+EG taken at one of the best measurement grid point.





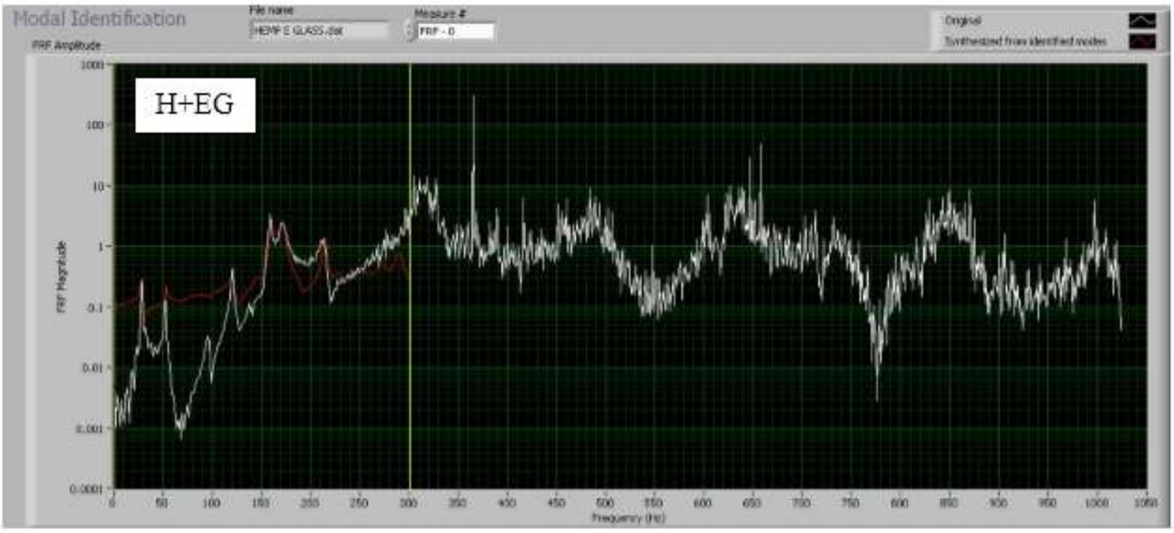


Fig.4 (b): Frequency Response Function Versus Frequency spectrum of H+B,H+C ,and H+EG taken at one of the best measurement grid point.

Table 3 Eigen values of the hybrid composite (Jute blended with Basalt, carbon-glass)

	Mode						
J+B		1	2	3	4	5	
	Eigen Values, Hz	36.403	70.367	123.69	208.922	221.002	

	Mode					
J+C		1	2	3	4	5
	Eigen Values, Hz	57.151	100.931	135.8326	228.221	301.577

	Mode						
J+EG		1	2	3	4	5	
	Eigen Values, Hz	38.889	75.121	119.824	223.135	299.961	

Table 4 Eigen values of the hybrid composite (Hemp blended with Basalt, carbon-glass)

	Mode						
H+B		1	2	3	4	5	
	Eigen Values, Hz	36.882	79.635	88.972	96.841	115.816	

	Mode					
H+C		1	2	3	4	5
	Eigen Values, Hz	47.453	114.409	154.228	240.972	272.917

H+EG	Mode						
		1	2	3	4	5	
	Eigen Values, Hz	28.648	52.725	158.884	172.429	214.656	

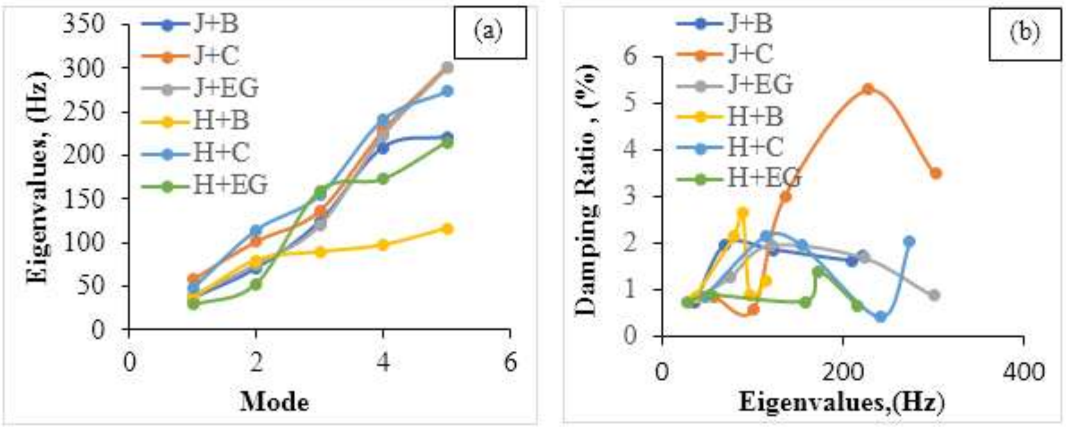


Fig.5: (a) Eigenvalue versus mode plot and (b) Damping ratio versus eigenvalues plot of all the fabricate composites

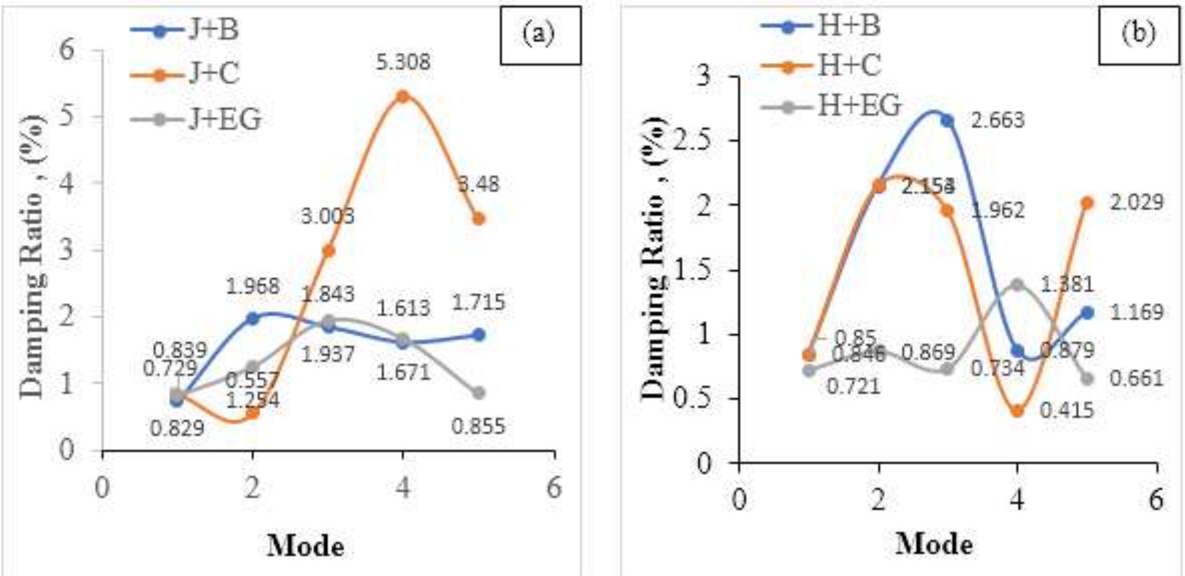
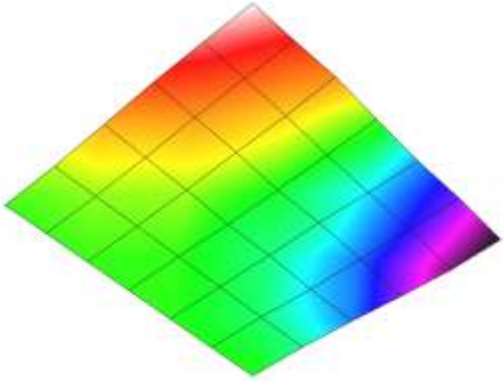
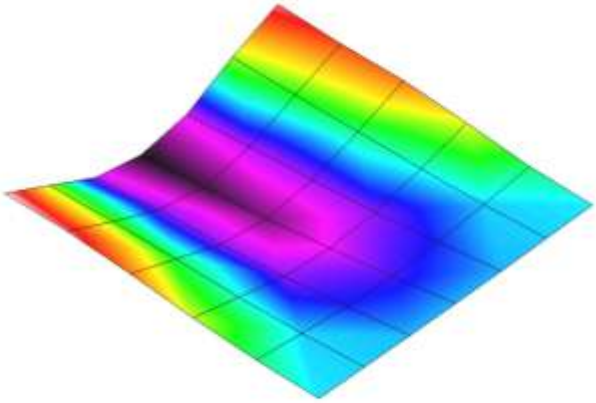


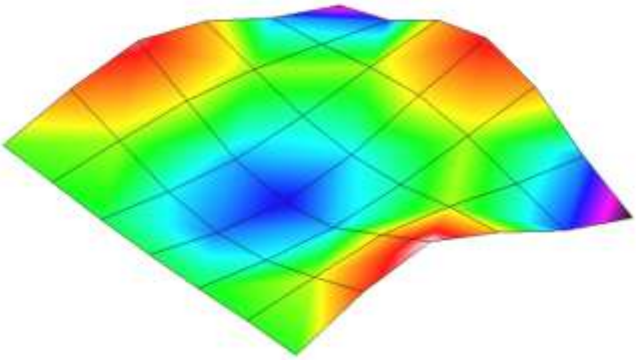
Fig.6: (a) Damping ratio versus mode plot when Jute combined with Basalt, Carbon & e-glass (b) Damping ratio versus mode plot when Hemp combined with Basalt, Carbon & e-glass.



First Mode: Twist (26.648 to 88.972 Hz.)



Second Mode: Bend (100.931 to 158.884 Hz.)



Third Mode: Twist & Bend (172.429 to 301.577 Hz.)

Fig.7: Mode shapes corresponding eigenvalues obtained from the labview software

4. Conclusions

There are a few important conclusions that can be drawn from the dynamic investigations of novel hybrid lumped composites using FFT analyser, and they are as follows:

1. The hybrid composites, namely J+EG and H+EG, have shown underdamped characteristics ($\xi<1$) and were found to be stable and attuned periodically, and may be recommended for structure-borne noise applications. Other hybrid composites, viz., J+B, J+C, H+B, and H+C, showed overdamped characteristics($\xi>1$) and may be used where overshooting is not a good outcome.
2. High eigenvalues recorded that lie between 429 and 301.577 Hz in the case of J+EG and H+EG indicated less stiffness in the lumped system and may be trade off before using the same in any structure-borne noise applications.
3. Due to their lower stiffness, J+EG and H+EG hybrid composites exhibited both twisting and bending characteristics. However, due to their underdamped characteristics, they may be ideal for practical applications.

Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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