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Vibration Analysis on PLA Coated Jute-Banana Fiber Reinforced Hybrid Composite Using Finite Element Method

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ABSTRACT: Hybrid laminates have been applied in a wide range of applications, including aircraft, automotive, and other areas requiring light weight and high strength. There are various types of hybrid laminates, and each laminate must be evaluated for its intended application. Most of the structural components are generally subjected to dynamic loading in their working lives. These components may be required to operate in a highly dynamic environment where vibration causes the most harm. Hence vibration analysis has become very important to know its effects in advance and to take necessary steps. The objective of the present work to find the natural frequency of biodegradable Jute-Banana fibre reinforced composite structure by using finite element analysis in ANSYS 2022 R2. The different composite plates with varying fibre content with three boundary conditions were modeled. Simulation is carried out on a standard plate of 350 x 350 x 4 mm³ with five layers of fibre woven materials. It has been concluded that among J, B and JB, JB composite observed the higher frequency in all modes of C-F-F-F, C-F-F-C and S-S-S-S boundary conditions. JB has recorded an increase in natural frequency of 14.88% compared to individual jute banana hybrid composite.

KEYWORDS: Composite, NFRC, vibration, damping properties, natural Frequency.

I. INTRODUCTION

With increasing in improvements in polymer technology more and more variety of synthetic fibres are being developed for industrial and all other applications. The most important part of the synthetic fibres is increase in wastage which creates a hazardous environment to both humans and all living beings. The process of degradation is slowed down [1]. As the degradation is very slow and creates a toxic environment (gases) when burnt so the researchers are in search of materials that are bio friendly and non-harming to environment. This created a huge demand to the Natural fibres which have good specific properties, low density, nontoxic [2]-[4]. They may be weak as compared to the synthetic fibres but on treating and coating it with different solutions will have an appreciable increase in their properties [5]. Natural fibre materials are more attractive materials having advanced properties with a wide range of applications, especially as structural materials. These fibres have a very good strength to weight ratio, specific properties are very cheap and very sustainable. The researchers have shown a great interest on these fibres in recent days. Especially fibres like flax, jute banana, hemp, sisal, coir [6] are found to have a good reinforcing effect in thermoset and thermoplastic and are investigated for packing [12], construction, marine, automobile and aerospace applications.

A composite fabric is a mixture of materials with unique physical and chemical residences. Whilst they are mixed, they invent a material this is specialized to do a sure process, as an instance, to end up more potent, lighter, or immune to strength. They can also enhance electricity and stiffness. Composite materials come in a variety of shapes and sizes, including carbon-bolstered fibre plastic, glass fibre-bolstered aluminum, carbon nanotube composites, and many others. Metal-matrix and ceramic-matrix composites are two further types of composites. Hybrid composites are composites that have two or more reinforcing fibres mixed. Carbon-aramid reinforced epoxy (which combines strength and impact resistance) and glass-carbon reinforced epoxy (which provides a robust material at a reasonable price) are the most prevalent hybrid composites [13]. When a combination of qualities from multiple types of fibres is desired, or when both longitudinal and lateral mechanical performance is required. Synthetic fibres are man-made fibres that are commonly used in the composites industry. However, they have a severe influence on the environment and human health [14], prompting us to seek more promising renewable materials, such as natural fibre reinforced composites

(NFRC). The majority of NFRCs use lignocellulosic fibres of various types, which have a lower density (1/2 that of glass fibres), are easy to recycle, are CO₂ neutral, and have satisfactory mechanical, thermal, acoustic, and insulating properties [15]. Schematic representation of a composite laminate is shown in figure 1.

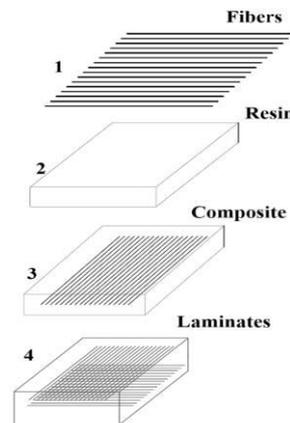


Fig.1: Schematic representation of a composite laminate

Natural fibres are fibres that are derived from renewable resources and are therefore long-lasting. Plants that generate natural fibres can be classed as main or secondary, depending on the source of usage. Primary plants are those that are grown solely for their fibres (ex: jute, sisal etc.). Secondary plants (examples: pineapple, coir, etc.) are those that produce natural fibres as by-products [4]. Natural fibres have a few drawbacks, such as hydrophilicity. Thermal stability is poor, characteristics are unpredictable, and wettability and compatibility are low. As a result, surface changes are thought to be effective treatment methods for overcoming these drawbacks and preparing improved natural fibre composites [3]. Jute fibre is the bark of the white jute plant (*Corchorus capsularis*) and, to a lesser extent, Tossa jute are used to make jute. Golden fibre is a natural fibre that has a golden and silky sheen to it. Jute is an annual crop that takes 120 days to mature (April/May-July/August) [1]. It thrives in tropical lowland regions with humidity levels ranging from 60% to 90%. Jute is a rain- 5 fed crop that requires no fertilizer or herbicides to grow. Yields per hectare are approximately 2 tons of dry jute fibre. Jute is one of the most affordable natural fibres, second only to cotton in terms of volume produced and kind of application of vegetable fibres. Where “Banana fibre, a lignocellulosic fibre obtained from the banana plant's pseudo-stem (*Musa septennium*), is a bast fibre with extraordinarily precise mechanical qualities [2]. A banana plant is a big perennial herb with pseudo stem-like leaf sheaths. Its apex can be 10-40 feet (3.0-12.2 meters) tall, with 8-12 big leaves surrounding it. The leaves can reach a length of 9 feet and a width of 2 feet (2.7 meter and 0.61 meters)”. “A banana plant can be found in Thailand and Southeast Asia, as well as India, Bangladesh, Indonesia, Malaysia, the Philippines, Hawaii, and several Pacific islands”. Epoxy refers to a group of basic additives and epoxy resin's cured end products. Epoxy resins, commonly known as poly epoxides, are epoxide-containing reactive prepolymers and polymers. Epoxy is another name for the epoxide functional group. [3] The tensile strength of thermoplastic epoxies ranges from 90 to 120 MPa. A tensile modulus of between 3100 and 3800 MPa . Glass transition temperature ranges between 150 and 220 degrees Celsius.

In continuation, the following are the major objectives of this work: To analyse hybrid jute and banana fibre reinforced composite structures for its free vibration characteristics for several parametric orientations. To evaluate natural frequency of composites at different boundary conditions using ANSYS 2020 R2. Comparison of natural frequencies of jute and banana hybridized composite laminates with bare jute composite and banana composite structure

II. MATERIALS AND METHODOLOGY

1.1. Materials

The hybrid laminates were made of jute fibre, banana fibre, and epoxy resin LY556 as the matrix. For individual jute fibre and banana fibre matrix, symmetrical lamination stacking sequences with five layers of unidirectional 0° and bi-axial 90° were opted, and for hybrid composite structure, the composition of jute to banana

fibres ratio was maintained at 2:5 with varying stacking sequences. The stacking sequence arrangement of laminates and fibre orientations is shown in Table 1.

Table1:Stackupsequence

Group	Laminate	Stacking
	Code	Sequence
Pure Jute laminate	J1	J ₅
Pure Banana laminate	B1	B ₅
Hybrid laminate with jute and banana fibre	JB	JB ₅

1.2. Specimen Geometries

The composite plate is prepared virtually in ANSYS software step by step. The plate were made to a dimension of 350 x 350 mm and mm thick plates with 5 layers of fibre. The specimen geometry as in Figure 2. The interface of the ANSYS 2020 R2 is user friendly the initial step to be proceeded is to model the component. There are no specific units selected since Ansys allows the user to follow any system of units. The part model is selected with the plane of 350 x 350 mm is drawn using rectangle and extruded to 4 mm

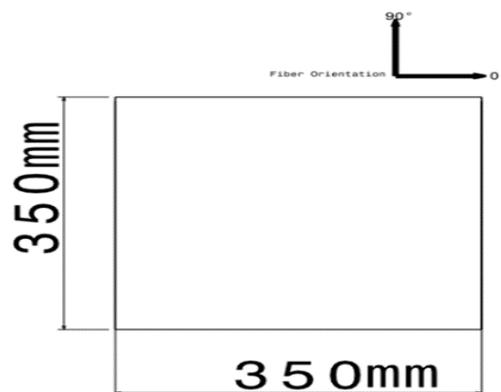
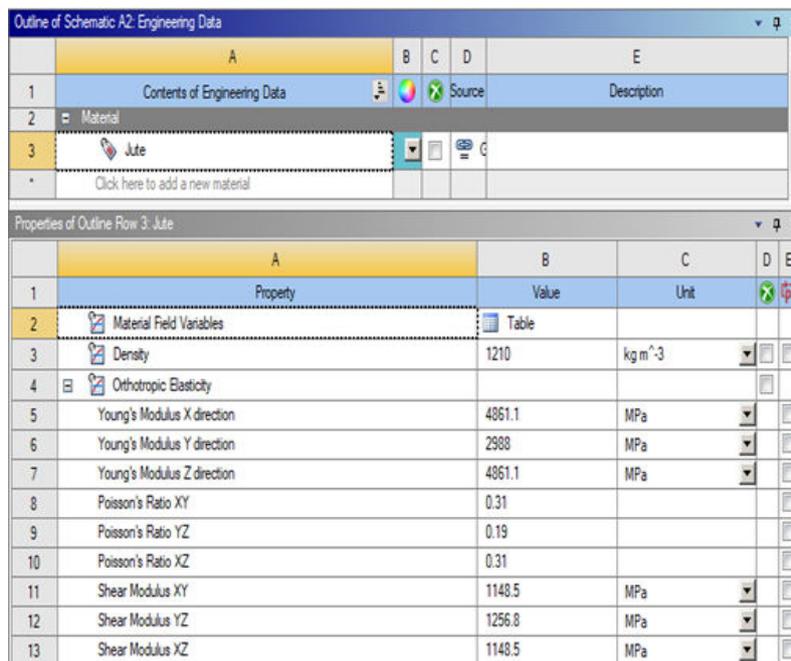


Figure2: Specimen geometry.

1.3. Methodology

All of the material data in Table 2 was used as input for the Engineering Data module in ANSYS Workbench [7], as shown in Figure 3. The design modeller was used to draught the specimen geometry after the material data was entered. The model was then meshed in ANSYS Mechanical. Depending on the specimen geometry, the mesh size was chosen from a range of 0.5 to 1 mm. C3D8R elements are eight-node linear hexahedral elements with minimal integration and hour glass control, were used to mesh the composite materials. Each part has meshing allocated to it, with a global mesh size of 0.8 mm and 24,500 elements as shown in figure 4. Mesh sensitivity is achieved by altering the mesh density and thickness within the plane. The mesh was then exported to ANSYS ACP-Pre for modelling, material

assignment, fibre orientation, and layer stacking. According to the specifications, each layer was assigned a material, fibre direction, and stack-up sequence. Each layer of the composite model was given a thickness of 0.4 mm, making the solid composite model 3.2 mm thick. Figure 5 depicts a schematic of the solid composite model demonstrating the fibre orientation of 45° with green arrows and 0° reference fibre direction with yellow arrows. For the application of loading and boundary conditions, the meshed solid composite model was transferred from ANSYS ACP to ANSYS modal analysis using APDL solver. According to the literature [9], The boundary condition is selected from the load section from mechanical category to symmetric/ asymmetric/ encaster is selected and the boundary condition of CFFF CFFC SSSS is arranged accordingly. For CFFC the specimen is clamped from two edges and two free and for CFFF specimen is clamped at one end and free at three edges. For SSSS specimen's U_x , U_y , R_x , R_y are freed.



Outline of Schematic A2: Engineering Data					
	A	B	C	D	E
1	Contents of Engineering Data			Source	Description
2	Material				
3	Jute				
Click here to add a new material					

Properties of Outline Row 3: Jute					
	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	1210	kg m ⁻³		
4	Orthotropic Elasticity				
5	Young's Modulus X direction	4861.1	MPa		
6	Young's Modulus Y direction	2988	MPa		
7	Young's Modulus Z direction	4861.1	MPa		
8	Poisson's Ratio XY	0.31			
9	Poisson's Ratio YZ	0.19			
10	Poisson's Ratio XZ	0.31			
11	Shear Modulus XY	1148.5	MPa		
12	Shear Modulus YZ	1256.8	MPa		
13	Shear Modulus XZ	1148.5	MPa		

Figure3:EngineeringdatamoduleinANSYS.

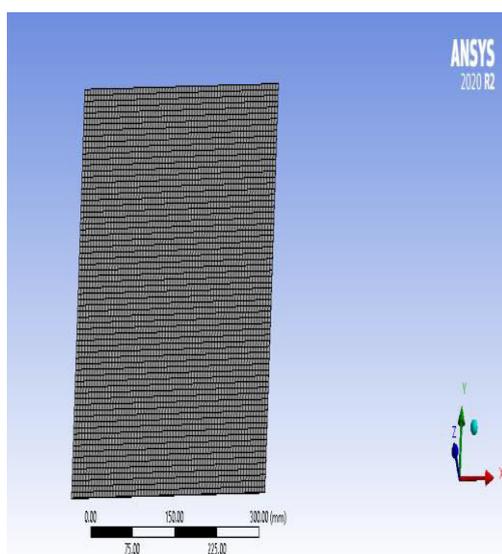


Figure4:Meshedmodel.

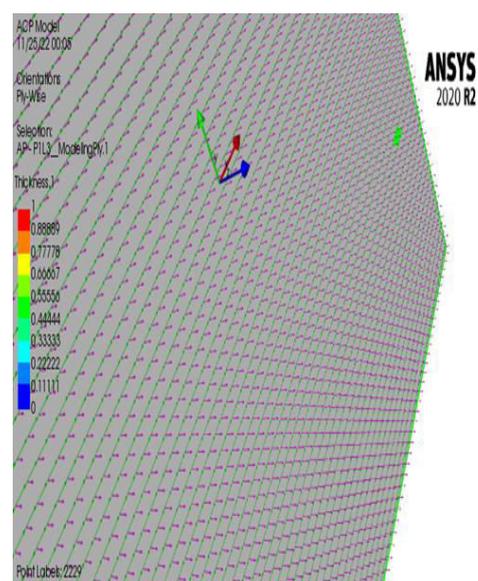


Figure5:FibreorientationinANSYSACP.

Table2: Combined material properties of matrix and fibres

Properties	Jute	Banana	Hybrid Jute + Banana
Density(kg/m ³)	1210	1230	1220
Young'sModulusinX-direction(MPa)	4861.1	2918.9	2885.9
Young'sModulusinY-direction(MPa)	2988	2881.5	2849.2
Young'sModulusinZ-direction(MPa)	4861.1	2881.5	2849.2
Poisson'sRatioXY	0.31	0.31	0.31
Poisson'sRatioYZ	0.19	0.301	0.31
Poisson'sRatioXZ	0.31	0.31	0.31
ShearModulusXY(MPa)	1148.5	1102.4	1086.2
ShearModulusYZ(MPa)	1256.8	1104.1	1088.5
ShearModulusXZ(MPa)	1148.5	1102.4	1086.2

III. RESULTS AND DISCUSSION

In this preliminary analysis, natural fibres like banana fibre is reinforced with another natural fibre namely Jute fibre with epoxy resin i.e., Two different fibres acts as the reinforcement material in the preparation of the hybrid composites. Their vibrational properties namely natural frequency, damping characteristics are found analytically. Analytical results are summarized in the tables and charts.

3.1.NATURAL FREQUENCY OF J1 LAMINATE

The J1 laminate consists of jute fibre 40% by volume and the matrix material to 60% by volume. The composite is tested to 3 different boundary conditions as CFFC- two ends clamped and two free, CFFFone end clamped and all free, SSSS- all sides simply supported. The maximum frequency that has been attained is in SSSS boundary condition 238.73Hz as the value from the table 3. The obtained natural frequency and its respective mode shapes is shown in figure 6-7.

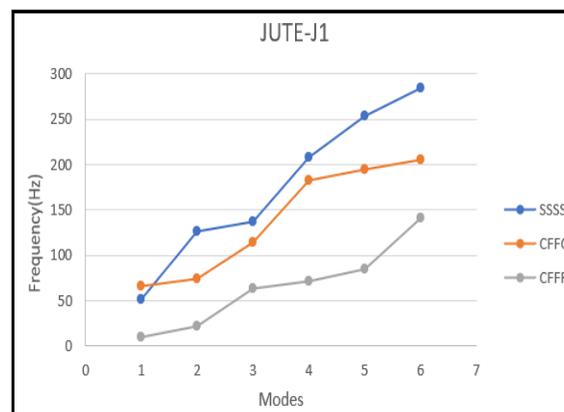


Figure6: Natural frequency of J1 composite

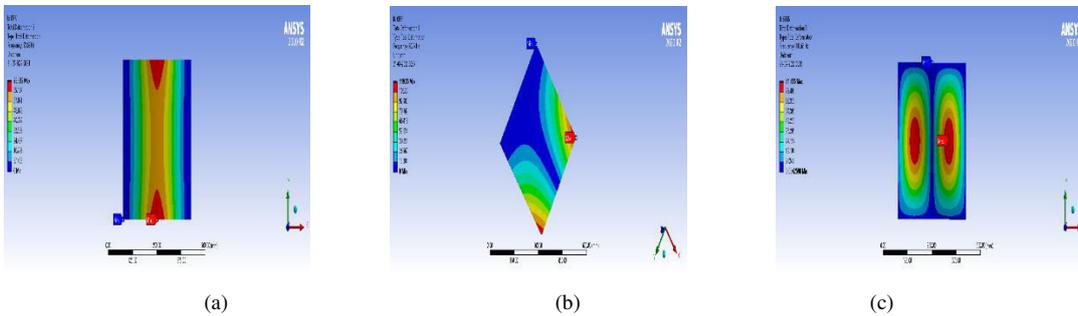


Fig.7.Mode shape of vibration of J1 laminate (a) One side clamped-CFFF (b) Two side clamped-CFFC (c) Four side simply supported-SSSS.

Table3:Natural frequency of J1 laminate.

Mode	CFFF (In hertz)	CFFC (In hertz)	SSSS (In hertz)
1	8.3983	53.62	47.633
2	20.37	63.594	118.65
3	51.387	104.7	118.67
4	65.441	147.95	190.39
5	74.315	162.1	238.02
6	129.8	191.86	238.73

3.2.NATURAL FREQUENCY OF B1 LAMINATE

The B1 laminate consists of banana fibre 20% by volume and the matrix material to 60% by volume. The composite is tested to 3 boundary conditions as shown in the table 4. It is observed from the table that the maximum frequency obtained is in mode 6 with 239.16Hz.The obtained natural frequency and its respective mode shapes is shown in figure 8-9.

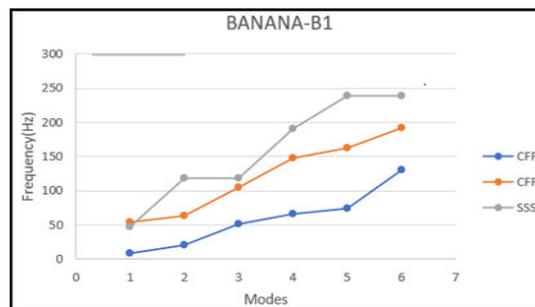


Figure8:Natural frequency of B1 laminate

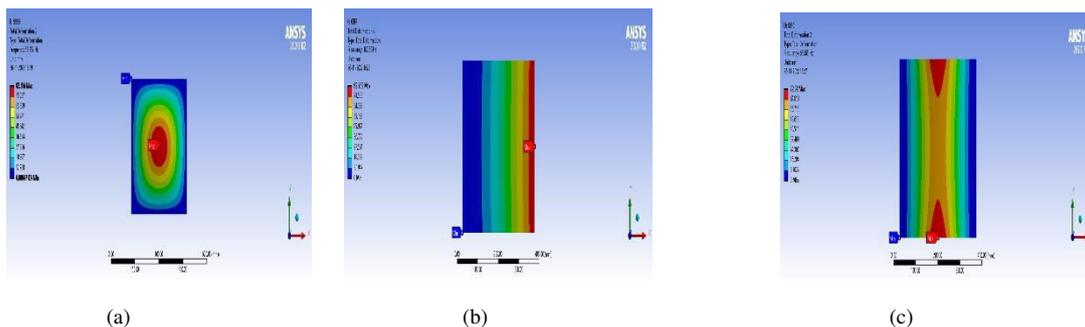


Fig. 9. Mode shape of vibration of B1 Laminate (a) One side clamped-CFFF (b) Two side clamped-CFFC (c) Four side simply supported-SSSS

Table4:Natural frequency of B1 laminate.

Mode	CFFF (in hertz)	CFFC (in hertz)	SSSS (In hertz)
1	8.4118	53.707	47.737
2	20.429	63.727	118.89
3	51.473	104.94	118.9
4	65.572	148.18	190.8
5	74.495	162.31	238.44
6	130.14	192.25	239.16

3.3. NATURAL FREQUENCY OF JB LAMINATE

The JB laminate consists of jute and banana fibre which makes it a hybrid composite with 20% fibre by volume in each case. The orientation of fibre in composite is made in $0^0-0^0-0^0-0^0-0^0$, such that a regular composite is created. The composite is tested to 3 boundary conditions as shown in the table 5. The modal analysis revealed that the mode 6 has the maximum frequency of 284.54Hz. The obtained natural frequency and its respective mode shapes is shown in figure 10-11.

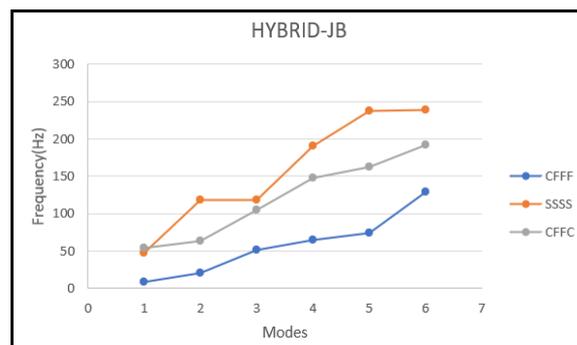


Figure10:Natural frequency of JB laminate.

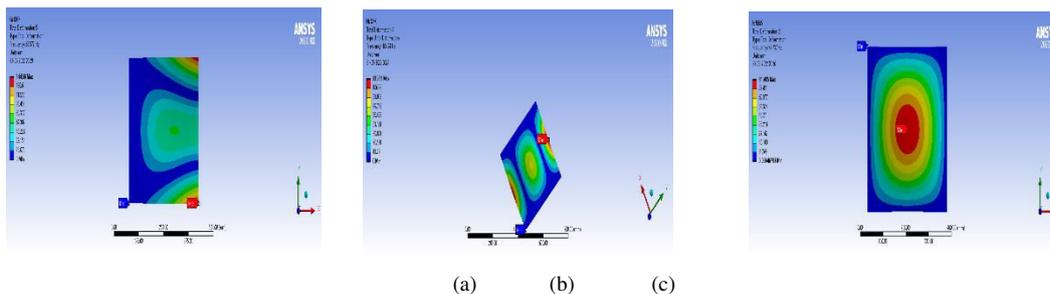


Fig. 11. Mode shape of vibration of JB Laminate (a) One side clamped-CFFF (b) Two side clamped-CFFC (c) Four side simply supported-SSSS

Table5:Natural frequency of JB laminate

Mode	CFFF (in hertz)	CFFC (in hertz)	SSSS (In hertz)
1	10.369	66.065	51.952
2	22.127	74.913	126.18
3	62.938	115.03	137.71
4	70.926	182.13	207.63
5	84.749	194.46	523.34
6	140.6	205.84	284.54

IV. CONCLUSIONS

In the present analytical study, woven jute fibre and banana and hybrid jute-banana composite plates is model in Ansys ACP pre and tested for modal analysis. The modal analysis has been carried out in finite element software called ANSYS 2020 R2, from the investigational results the follow are the conclusions drawn:

- The modal analysis results have concluded that among J1 and B1 laminates, B1 has higher natural frequency in mode 6 (CFFF-130.14Hz, CFFC-192.25Hz, SSSS-239.16Hz)of boundary condition. Whereas in J1 and B1 laminates,B1 has higher natural frequency in SSSS boundary condition.
- On comparing J1 and B1 with hybrid JB it has been observed that JB hybrid composite recorded the higher frequency in all modes of CFFF, CCCC and SSSS boundary conditions.
- It can also be inferred from graphs that JB composite possess high natural frequency in all modes especially in mode 6 (CFFF-140.6Hz, CFFC-205.84Hz, SSSS-284.54Hz) irrespective of boundary conditions applied since the fibres are unidirectional resulting in higher stiffness of the material.

Aspartofthefuturescope, following research can be extended to combination of natural and synthetic fibre composite may lead to a higher vibrational property. By varying the fibre loading content and its effect on vibrational property can be studied. Changing the fabrication technique of composite and its effect can on vibrational behaviour can be studied.

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