Free Vibration Analysis of Natural Fiberized Polymer Composite

Ajay Joseson T [1], Ashick S [2], Ashwin A[3], Arun Raj G[4]
[1, 2, 3] Dept of mechanical engineering
[4]Assistant professor, Dept of mechanical engineering
[1, 2, 3, 4] Ponjesly college of engineering, Nagercoil - 629003

Abstract- *This paper mainly presents the free vibration analysis of isotropic rectangular beam using Block-Lanczos method. This analysis has been held for two polymer matrix based composite materials with reinforcements are E-Glass and Coir fiber with same dimensions and their orientations are 0°, 90° and 180° of three layers. The result from the Block-Lanczos method is compared with those results obtained from computerized data acquisition system (DEWE 43, Dewetron Corp, Austria) based Cantilever Beam Vibration Technique and the beam is treated as a cantilever for testing, and the results of free vibration has been taken for three modes with the use of an accelerometer (Kistler model 8778A500) and an impact hammer (Kistler model 9722A500). Based on Euler's Theory the free vibration of the beam is numerically calculated by taking young's modulus, density and Poisson's ratio as constants. Commercially available ANSYS software is used to do the modal analysis of beam by taking eight elements. All the results of the three methods are well correlate with each other and by comparing the free vibration results of E-Glass and Coir fiber, Coir fiber produced very low vibration in all the three analysis. So it is proposed to use Coir fiber as reinforcement material in place where E-Glass is currently used.*

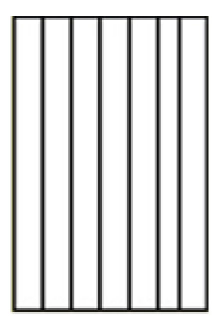
Keywords- Isotropic rectangular beam, Polymer matrix, E-Glass and Coir fiber, Free vibration, Block-Lanczos method, Cantilever Beam Vibration Technique, Euler's Theory

I. INTRODUCTION

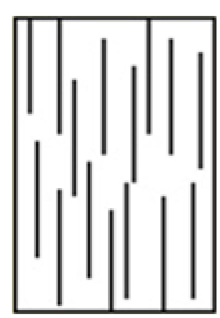
Composite Material

A composite material is a material system composed of a suitably arranged mixture or combination of two or more micro- or macro- constituents with an interface separating them that differ in form and chemical composition and are essentially insoluble in each other. At the atomic level materials such as some metal alloys and polymeric materials could be called composite materials since they consist of different and distinct atomic groupings. Material property combinations and ranges have been, and are yet being, extended by the development of composite materials. Generally speaking, a composite is considered to be any multiphase material that exhibits a significant proportion of the properties of both constituent phases such that a better combination of properties is realized. According to the principle of combined action, better property combinations are fashioned by the judicious combination of two or more distinct materials.

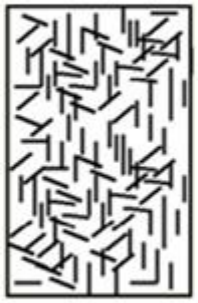
Many composite materials are composed of two phases; one is termed the matrix, which is continuous and surrounds the other phase, other called the dispersed phase. The properties of composites are a function of the properties of the constituent phases, their relative amounts, and the geometry of the dispersed phases. "Dispersed phase geometry" in this context means the shape of the particles and the particle size, distribution, and orientation. One simple scheme for the classification of composite materials , which consists of three main divisions: particle-reinforced, fibre-reinforced, and structural composites; also, at least two subdivisions exist for each. The dispersed phase for particle-reinforced composites is equiaxed (i.e., particle dimensions are approximately the same in all directions); for fibre-reinforced composites, the dispersed phase has the geometry of a fibre (i.e., a large length-to-diameter ratio). Structural composites are combinations of composites and homogeneous materials. The discussion of the remainder of this chapter will be organized according to this classification scheme. The fiber orientations in fiber reinforce



Continuous and aligned fibres



Discontinuous and aligned fibres



Discontinuous and randomly oriented fibres

II. MATERIALS AND EQUIPMENTS

Material

This part of this paper presents the methods and equipment's used to make composite materials. Here we have used the following materials to develop composites.

- Matrix – Polyester
- Reinforcements – a. Coir fiber
  b. E-glass
- Accelerator -- Methyl ethyl ketone peroxide (MEKP)
- Catalyst -- Cobalt naphthenate

Polyester resin

Polyester resins are unsaturatedresins formed by the reaction of dibasicorganicacids and polyhydric alcohols. Polyester resins are used in sheet molding compound, bulk molding compound and the toner of laser printers. Wall panels fabricated from polyester resins reinforced with fiberglass — so-called fiberglass reinforced plastic (FRP) — are typically used in restaurants, kitchens, restrooms and other areas that require washable low-maintenance walls.

Unsaturated polyesters are condensation polymers formed by the reaction of polyols (also known as polyhydric alcohols), organic compounds with multiple alcohol or hydroxyl functional groups, with saturated or unsaturated dibasic acids. Typical polyols used are glycols such as ethylene glycol; acids used are phthalic acid and maleic acid. Water, a by-product of esterification reactions, is continuously removed, driving the reaction to completion. The use of unsaturated polyesters and additives such as styrene lowers the viscosity of the resin. The initially liquid resin is converted to a solid by cross-linking chains. This is done by creating free radicals at unsaturated bonds, which propagate in a chain reaction to other unsaturated bonds in adjacent molecules, linking them in the process. The initial free radicals are induced by adding a compound that easily decomposes into free radicals. This compound is usually and incorrectly known as the catalyst. Substances used are generally organic peroxides such as benzoyl peroxide or methyl ethyl ketone peroxide.

Polyester resins are thermosetting and, as with other resins, cure exothermically. The use of excessive catalyst can, therefore, cause charring or even ignition during the curing process. Excessive catalyst may also cause the product to fracture or form a rubbery material.

Coir Fiber

The studied composite material is made of polyester matrix reinforced with Coconut fibers which were arranged in discontinuous randomly oriented configuration. Basically, the coir fibers obtained from the coconut husk which was abstracted from coconut fruit. After they had been abstracted, the coir fibres will be dried at 70°C to 80°C using drying oven. In order to avoid degradation factor, the coir fibers need to go through the treatment process. But hare we have done experiments without any treatments in order to enumerate its naturally available natural frequency.

Material Preparation

Coir fibers are reinforced in unsaturated isophthalic polyester Resin to prepare the composite. The composite slabs are made by conventional hand lay-up molding Technique. Two percent cobalt naphthalene (as accelerator) is mixed thoroughly in isophthalic polyester resin and then 3% methyl-ethyl-ketone-peroxide (MEKP) as hardener is mixed in the resin prior to reinforcement. This mixture is handled in the iron mould . The castings are put under load for about 3 to 4 hours for proper curing at room temperature. Similar procedure adapted for the preparation of the Glass fiber polymer composites. Coir fiber after this process is chopped into equal pieces of 20mm breadth.

Coir fiber

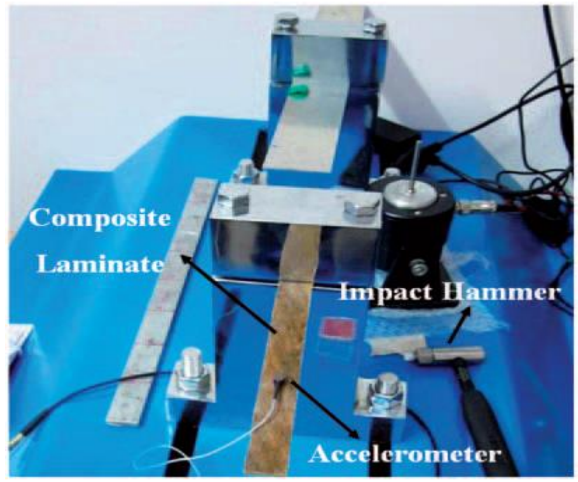
preparations on Coir fiber

Iron mould (200x200mm)

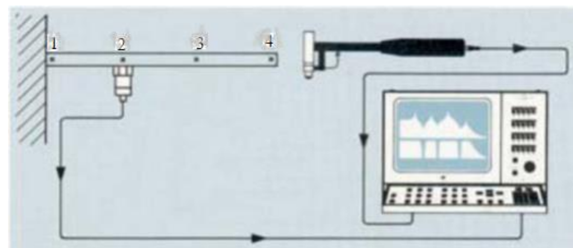
Coir fiber specimens

E-glass fiber specimen

III. EXPERIMENTAL SETUP FOR MODAL ANALYSIS



Experimental setup for modal analysis

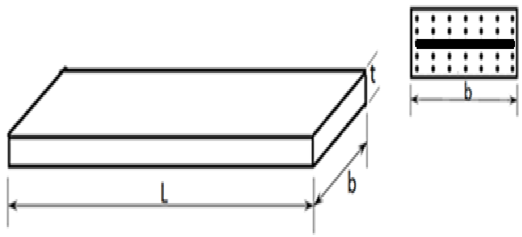


Line diagram of Experimental setup

The experimental setup used to carry out the modal analysis of coconut sheath/clay-reinforced hybrid composite laminates using impact hammer. The accelerometer (Kistler model 8778A500) is attached at the end of rectangular composite laminate with wax. The modally tuned impact hammer (Kistler model 9722A500) with sharp hardened tip is chosen for getting higher frequencies. The displacement signal from accelerometer has been recorded in personal computer through data acquisition system (DEWE 43, Dewetron Corp., and Austria) and ICP conditioner (MSIBRACC). Two separate adaptors are used for capturing the output signal, one for receiving accelerometer signal and the other for measuring the magnitude of the response by the hammer from laminates.

IV. DYNAMIC MECHANICAL ANALYSIS (DMA)

Dynamic mechanical properties such as storage modulus (E 0) and loss tangent (tan d) were measured by using SII EXSTAR DMS 6100 – DMA instrument. The rectangular composite specimens of size 200mm_20mm_3mm were used. It can be easily understood by viewing . The test was conducted by using 3-point bending mode. The samples were tested in a nitrogen atmosphere in a fixed frequency mode of 20 Hz and a heating rate of 2_C/min. The measurements were taken over a temperature range of 20_C–300_C.



Section of beam

The results obtained from the free vibration tests are tabulated in the Table 4.1 for three modes. This test was done for four specimens in both Coir and E-glass fibres and the average of four is considered for comparison with Euler's theory and ANSYS.

Table 4.1 Experimental Natural Frequency results of Coir and E-glass fiber in Hz

Sl.NO	Specimens	Mode1
1	EF -TR1	51.20
2	EF –TR2	38.00
3	EF –TR3	35.92
4	EF –TR4	39.20
5	CF -TR1	27.47
6	CF –TR2	27.60
7	CF –TR3	30.25
8	CF –TR4	31.19

V. RESULT AND DISCUSSION

Experimental Results

Experimental results of Coir and E-glass found by computerized DAQ based cantilever vibration setup with use of an accelerometer (Kistler model 8778A500) and an impact hammer (Kistler model 9722A500) are listed in Table 6.1. Table 6.2 shows the average values of frequency found for these four trials.

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8	CF –TR4	31.19

Table 6.2 Experimental average values of Natural Frequency of Coir and E-glass fiber in Hz

Sl.NO	Mode1	Mode2	Mode3
E-glass fiber	41.08	279.19	773.58
Coir fiber	29.13	167.35	551.24

This experiment was done for four trial specimens in order to get best result. Free vibration values of the trials have some difference, this may be due to the loses in hand lay-up method. Figure 6.1 shows the frequency variation of Coir and E-glass fiber in each mode.

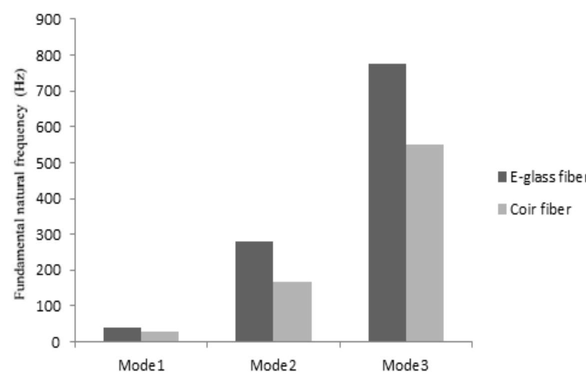

Figure 6.1 Variation of Experimental frequency in each mode

ANSYS Results

Experimental test was done by taking nine node i.e. eight element in the apparatus. So ANSYS analysis for the model said done for 8x2 elements. The results of the ANSYS analysis are listed in Table 6.3.

Table 6.3 Natural frequency of fibers from ANSYS in Hz

Sl.NO	Mode1	Mode2	Mode3
E-glass fiber	35.14	228.22	686.84
Coir fiber	27.12	176.13	530.10

Variation of the above table can be clearly identified by figure 6.2.

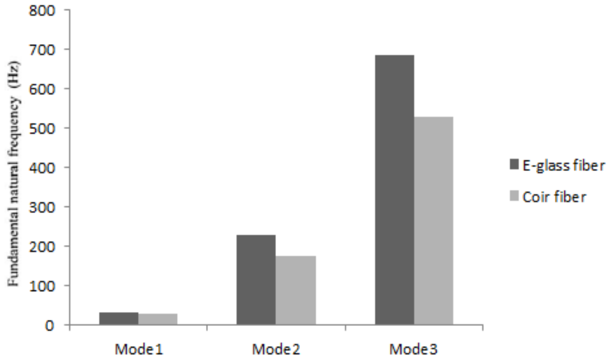

Figure 6.2 Variation of ANSYS frequency in each mode

In each mode ANSYS assumes a mode shape for the modeled beam. This mode shape is necessary to identify the shape of beam in extreme vibrations. Mode shapes of the modeled Coir fiber beam is shown in figure 6.3 to 6.5 and he same for E-glass is shown in figure 6.6 to 6.8.

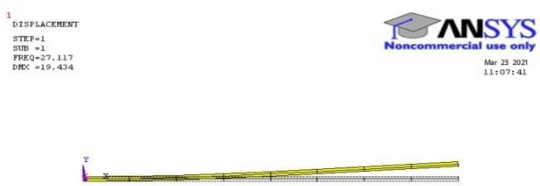

Figure 6.3 Frequency and Mode shape of Coir fiber in mode 1

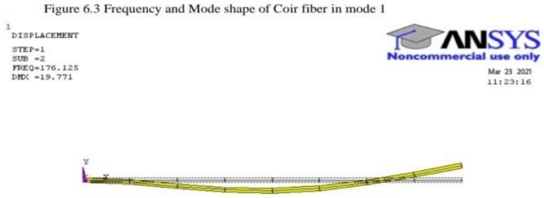

Figure 6.4 Frequency and Mode shape of Coir fiber in mode 2

5.8

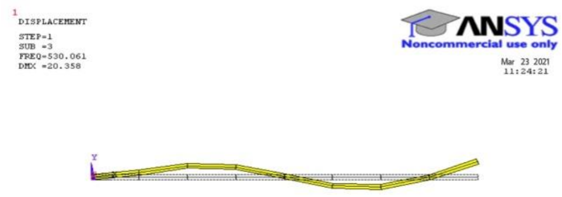

Figure 6.5 Frequency and Mode shape of Coir fiber in mode 3

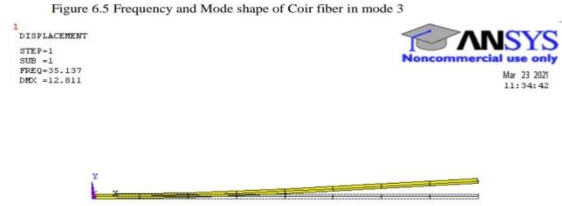

Figure 6.6 Frequency and Mode shape of E-glass fiber in mode 1

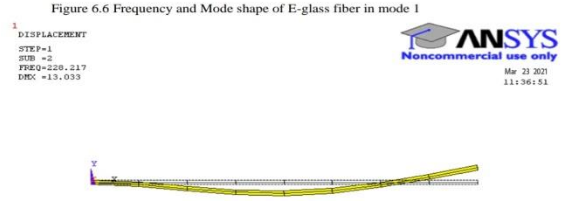

Figure 6.7 Frequency and Mode shape of E-glass fiber in mode 2

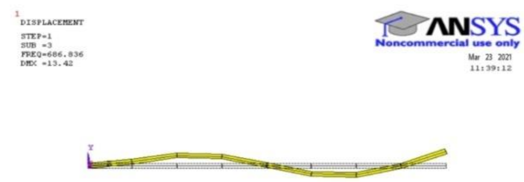

Figure 6.8 Frequency and Mode shape of E-glass fiber in mode 3

Euler's Theory Results

In this present work the Euler's theory is used for the numerical calculation of free vibration for the proposed two composites. Based on Euler's theory, the equation is

$$\omega_1 = 1.875^2 \sqrt{\frac{EI}{\rho A L^4}} \quad 5.8$$

$$\omega_2 = 4.694^2 \sqrt{\frac{EI}{\rho A L^4}} \quad 6.1$$

$$\omega_3 = 7.854^2 \sqrt{\frac{EI}{\rho A L^4}}$$

By using the above equation sample calculation was made and presented in chapter 5. The results from the above equation are tabulated in Table 6.4.

Table 6.4 Numerical Natural Frequency results of Coir and E-glass fiber in Hz

Sl.NO	Mode1	Mode2	Mode3
E-glass fiber	35.02	219.49	614.50
Coir fiber	27.025	169.37	474.18

Variation of the above table can be clearly identified by figure 6.10.

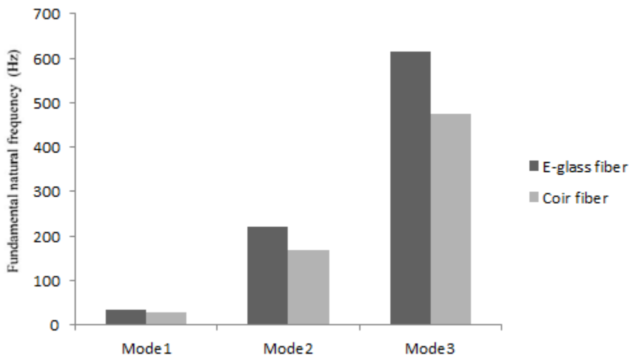

Figure 6.9 Variation of Numerically calculated frequency in each mode

Comparison for Results

This section presents the comparison of the above said results. Figure 6.11 to 6.13 explain about the free vibration in mode 1 to mode 3.

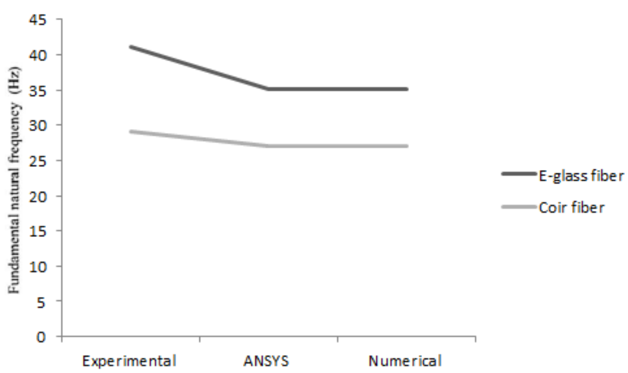

Figure 6.10 Frequency of fiber in Mode 1

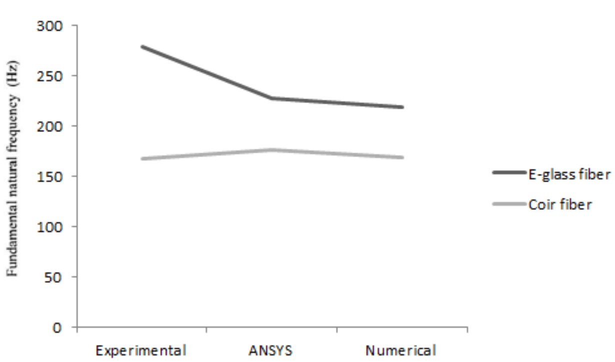

Figure 6.11 Frequency of fiber in Mode 2

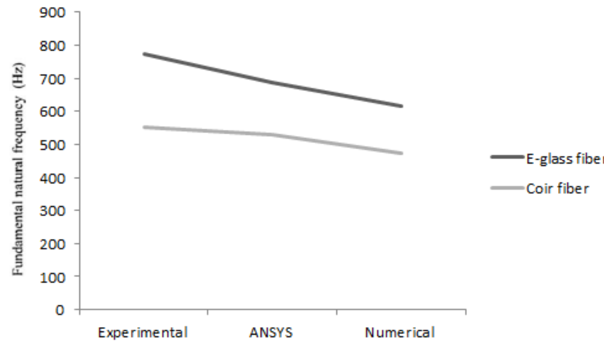

Figure 6.12 Frequency of fiber in Mode 3

Form the above figures, we can take a thing that experimental result give little high vibration compared to other methods. These is due to inconsiderable factors such as minute wind flow and uninform fiber alignment in hand layup method. Away from experimental result ANSYS result gives little equal frequency to Euler's theory result because these two does not consider any unexpectable losses so we can consider the experimental results as composite fee vibration. And among two fibers Coir gives less vibration so it can be used for any structural applications.

VI. CONCLUSION

In this paper, the free vibration analyses of Coir and E-glass fiber reinforced composites are investigated by computerized DAS based cantilever beam vibration method by taking eight equal elements. The results of the fibers are checked for modal analysis in ANSYS by taking 8x2 element discretization. Block-Lanczos method is chosen in ANSYS due to its characteristics and material's young's modulus and poison's ratio are calculated by doing series of three point bending tests. Archimedes principle is used for calculating density with these properties numerical calculations are made to evaluate the performance of the two methods. All the three methods produced small percentage of error, this may be due to improper alignment in specimen manufacturing and loses at the edges of the element in ANSYS. By comparing the free vibration results of Coir and E-glass, Coir produces low vibration than the commercially used E-glass. So it is to conclude that the Coir is the best of two in vibration characteristics

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