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Effect of Matrix Material on the Free Vibration Characteristics of Phoenix sp. Fiber Reinforced Polymer Matrix Composites

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Abstract

This study deals with the effect of matrix material (Isophthallic polyester and Epoxy) on the free vibration characteristics (natural frequency) of Phoenix Sp. fiber reinforced polymer matrix composites. The composite were prepared by varying the fiber length (10, 20 and 30 mm) and fiber volume fraction (10, 20, 30, 40 and 50%) with random fiber orientations using hand layup method followed by compression molding technique. The composite samples with cantilever boundary condition was tested by using the standard experimental setup consisting of fixture, an accelerometer, data acquisition kit and a personal computer to determine their natural frequencies. The results revealed that, the matrix material has significant effect on the natural frequency values, due to the variation in their compatibility with the reinforcing fibers. The composites prepared with epoxy matrix showed good free vibration property than that of the composites prepared with isophthallic polyester resin.

Keywords: Phoenix Sp., Vibration, Natural fiber, Polymer matrix composites, Frequency;

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Nomenclature

SFPC	Sisal Fiber Polyester Composites
BFPC	Banana Fiber Polyester Composites
FNF	Fundamental Natural Frequency

1. Introduction

Natural fiber reinforced composite materials possessing better properties such as, high strength, lightweight, low cost, corrosion resistance, availability and high fatigue resistance. Based on this uniqueness it found its application in the aerospace, automotive, construction, domestic and sporting goods etc. [1-5]. Rajeshkumar et al. [6] investigated the physical, chemical and vibration properties of raw Phoenix sp. fibers reinforced composites. The properties were determined by varying the fiber length (10, 20, 30, 40 and 50mm) keeping constant weight fraction of 10%. The results revealed that the 50mm length fiber reinforced composites yield better free vibration properties. Senthilkumar et al. [7] reported the free vibration characteristics of short Sisal Fiber Polyester Composite (SFPC) and short Banana Fiber Polyester Composite (BFPC) samples having dimension of 200x20x3 mm^3. The result indicated that the mechanical and damping properties increased with the increase in fiber content.

In addition to single fiber reinforced composites, some literatures reported the free vibration properties of hybrid composites. The results revealed that the vibration properties are enhanced by reinforcing two or more fibers in the same composite materials. Rajesh et al. [8] assessed the free vibration behavior of banana /sisal natural fibers reinforced hybrid polymer composites. First three bending modes are associated with natural frequency are considered for the analysis. The results indicated that 50 wt% fiber reinforced composites have maximum natural frequency when compared to the other composites. Senthil Kumar et al. [9] addressed the vibration properties of coconut sheath/sisal hybrid composites. Fabrication was done by using compression molding technique with varying stacking sequences. The result indicated that the treated fibers increased the natural frequency of pure and hybrid composites. Rajini et al. [10] determined the effect of nano-clay and chemical treatments on the free vibration properties of coconut sheath fiber polyester composites. The results showed that the addition of clay upto 3wt% increased the vibration properties and degradation was observed for the further increase in clay content. Moreover the chemical treatments also influenced the free vibration properties of composites.

The vibration behavior of synthetic fiber reinforced composites was modified by adding natural fibers. Rajini et al. [11] analyzed the free vibration behavior of hybrid composites developed by using naturally woven coconut sheath/E-glass/nano-clay reinforced in unsaturated polyester resin. Moreover the influence of alkali and silane treatments and stacking sequence were investigated. The obtained results showed that the addition of nano-clay increased the vibration properties and the stacking sequence of coconut sheath/coconut sheath/glass with alkali treated fibers affords optimum increase in vibration properties.

The variations in fiber length and volume fraction greatly influenced the vibration properties compared to chemical treatments and hybridization is observed from the above literatures. Moreover no literatures reported the influence of matrix material in the vibration properties. In this context, the present study deals with the effect of fiber length, volume fraction and matrix material on the free vibration properties of Phoenix sp. fiber reinforced polymer matrix composites.

2. Materials and methods

2.1. Fiber and Matrix

The Phoenix sp. fibers belong to Arecaceae family is found widely in India, China, Turkey, Canary, Africa, Island, etc. where the ground water level is high. This plant has more amounts of fibers in its petioles. The petioles are cut from the plant by using knife and are immersed in water. During this water retting process the unwanted materials present in the each petiole are removed. Then single fibers were extracted by manual peeling process Finally, the extracted fibers are washed in running water and dried at room temperature for 2-3 days. Then the fibers were cut to the required length (10, 20 and 30 mm) by using scissors. The properties of the Phoenix sp. fiber is shown in Table 1.

Table 1. Property of Phoenix sp. fiber. [6, 12, 13, 14]

Property	Values
Diameter (mm)	0.5766
Density (g/cc)	1.2576
Cellulose (%)	76.13
Lignin (%)	4.29
Moisture (%)	10.41
Wax (%)	0.32
Ash (%)	19.69
Tensile strength (MPa)	349
Young's modulus (GPa)	7.62

The epoxy resin (LY556) and amine-based hardener (HY951) are used for the fabrication of composites. The mixing ratio of 9:1 by weight is followed for all samples. The densities of epoxy and hardener are 1.15–1.20 g/cm^3 and 0.97–0.99 g/cm^3, respectively. For the second case isophthallic polyester resin with Methyl Ethyl Ketone Peroxide (accelerator) and Cobalt Naphthalene (catalyst) is used for the preparation of composites [6, 12].

2.2. Preparation of Composite samples

The steel die having dimensions 250x200x3 mm^3 is used to prepare the composite panels by using compression molding process. Initially the polishing wax is applied at the inner surface of the die. Then the fibers were spread over the female die randomly and resin mixture is poured on to it. After that the male die is placed over the female die and pressure is applied by using hydraulic press. After curing the samples for testing is prepared by cutting the obtained composite plate using saw.

2.3. Modal analysis

The experimental setup used to obtain the natural frequencies of Phoenix sp. fiber reinforced composites is shown in Fig. 1. The arrangement consists of fixture, impact hammer (Kistler model 9722A500), accelerometer (Kistler model 8778A500), data acquisition card (DAS DEWE43, Dewetron corp., and Austria) and a personal computer. One end of the sample is fixed by using fixture and accelerometer is fixed at the other end by using wax.

3. Results and Discussions

In the Phoenix sp. fiber reinforced composites, the natural frequency depends on many factors like fiber length, fiber orientation, fiber volume fraction and fiber-matrix interface. The Fundamental Natural Frequency (FNF) of Phoenix sp. fiber reinforced epoxy composites and polyester composites are shown in Fig. 2 and Fig. 3, respectively. From Fig 2 it is noted that the FNF increased with the increase in fiber length irrespective of fiber volume fraction representing that the Phoenix sp. fiber has excellent vibration properties.

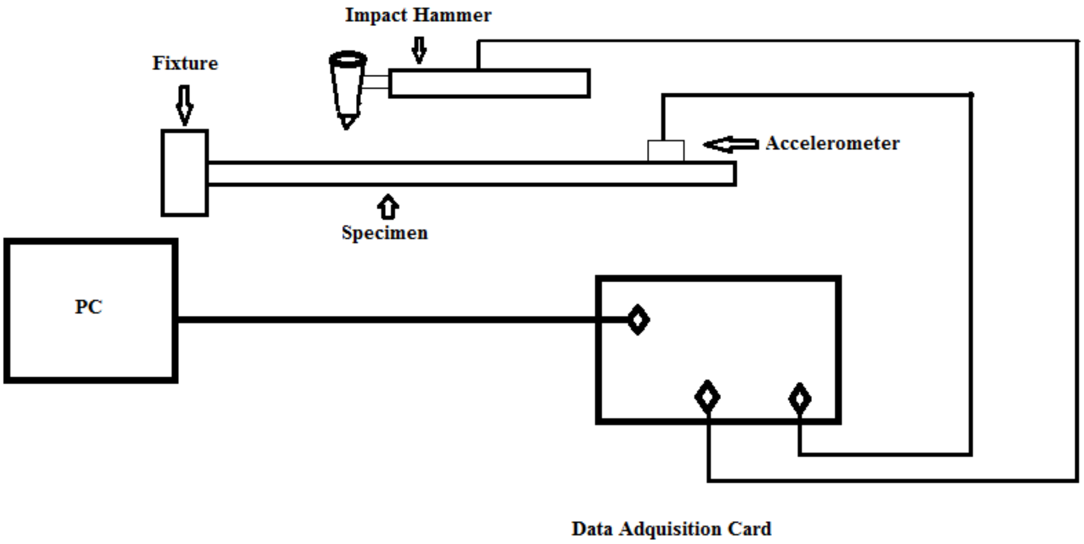

Fig. 1. Experimental set up for modal test.

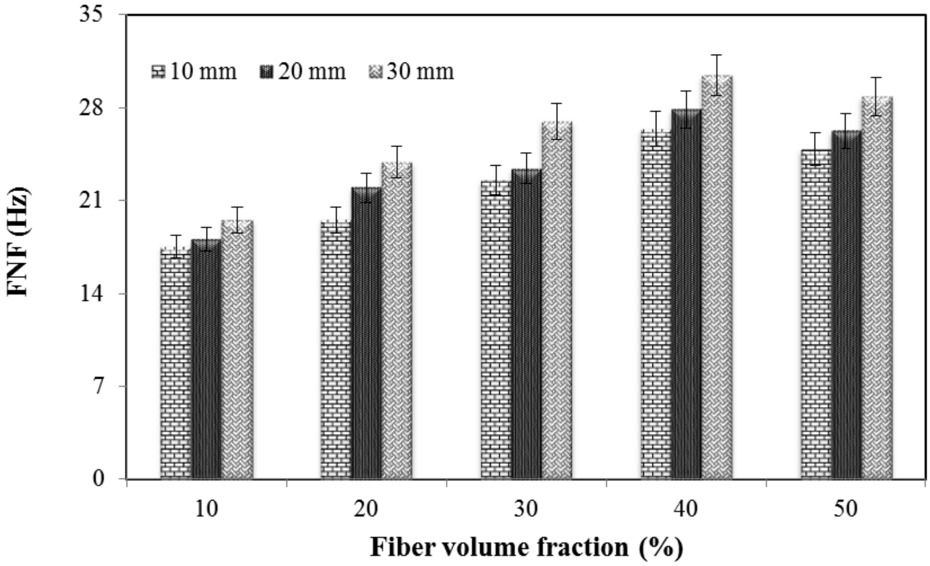

Fig. 2. FNF of Phoenix sp./epoxy composites.

Moreover the FNF increased with the increase in fiber volume fraction upto 40% and decreased with the further increase in fiber volume fraction. This degradation at higher volume fraction is due to insufficient matrix in the composites. Higher FNF of 30.44 Hz is noted for the composites reinforced with 30mm fiber at 40% volume fraction.

Fig. 3 shows the similar trend of FNF for polyester composites. As discussed previously the variations in fiber length and volume fraction has significant effect on the FNF. The polyester composites showed lower FNF compared to that of epoxy matrix composites indicating the poor damping property of polyester resin. The polyester composites records higher natural frequency of 26.85 Hz, which is 11.8% lower than that of the epoxy matrix composites.

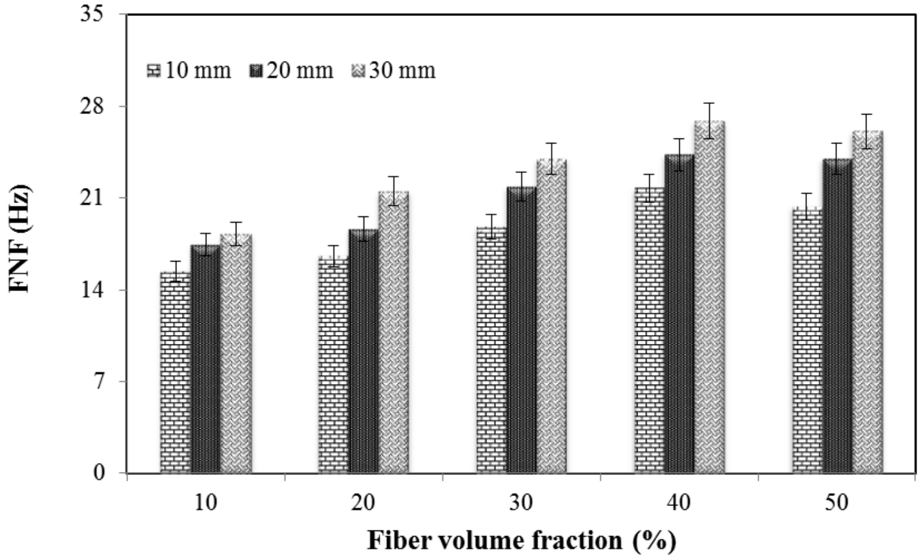

Fig. 3. FNF of Phoenix sp./polyester composites.

4. Conclusions

The composites were successfully fabricated by using epoxy and polyester matrix reinforced with Phoenix sp. fiber and obtained the following results.

- The FNF increased with the increase in both fiber length and fiber volume fraction.
- Higher content of fiber degrades the FNF of composites due to insufficient bonding.
- The polyester resin has lower damping property compared to that of the epoxy resin leading to lower FNF of polyester composites.

In conclusion the Phoenix sp. fiber is suggested as a good reinforcement agent for the fabrication of composites subjected to dynamic loading conditions.

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