RESEARCH ARTICLE

Fast Fourier Transform (FFT) Studies of Sisal Fiber Reinforced Polymer Composites

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ABSTRACT: This paper represents vibration analysis of Sisal fiber reinforced epoxy based composites using Fast Fourier Transform (FFT) analyzer. The composites were prepared by melt-mixing method, followed by compression molding process. The percentage of sisal fiber is varied from 4% to 10% in steps of 2%. Thermo gravimetric analysis (TGA) is done to understand moisture absorption and moisture content. We also report vibrational analysis to understand the influence of fiber loading on natural frequency and damping coefficient.

KEYWORDS: Sisal fiber, reinforced polymer composites, epoxy resin, FFT analyzer

1. INTRODUCTION

In recent years the use of composite materials were in demand on the basis of unique properties the systems which have novel applications in almost all industries, including aviation, engineering and automotive[1]. They have also gain attention due to their nano-structure possessing specific magnetic properties like high magnetization and coercitivity, high anisotropy [1-3]. Fibres obtained from the various parts of the plants are known as vegetable fibres. Many of the plant fibres such as coir, sisal, jute, banana, palmyra, pineapple, talipot, hemp, etc. find applications as a resource for industrial materials [4-5].

The use of natural plant fibers as a reinforcement in fiber-reinforced plastics (FRP) to replace synthetic fibers such as glass is receiving attention, because of advantages such as renewability, low density, and high specific strength. Recent studies have investigated the development of biodegradable composite materials using natural fibers such as flax [6], silk [7] bamboo [8], pineapple [9-10], oil palm empty fruit bunch [11-12], rice husk [13], jute [14], kenaf [15], sisal [16-17], and ramie [18] as reinforcement for biodegradable plastics.

A property of plant fibres depends primarily on the nature of the plant, locality in which it is grown, age of the plant, and the extraction method used. A coir is a hard and tough multicellular fibre with a central portion called “lacuna”. Sisal is an important leaf fibre and is very strong. Pineapple leaf fibre is soft and has high cellulose content. Oil palm fibres are hard and tough, and show similarity to coir fibres in cellular structure [19]. Apart from cellulose, plant fibres comprises of distinct natural substances. The elementary unit of a cellulose macromolecule is anhydro-d-glucose, which contains three alcohol hydroxyls (-OH) [4, 5, 20]. These hydroxyls form hydrogen bonds inside the macromolecule itself (intra-molecular) and between other cellulose macromolecules (inter-molecular) as well as with hydroxyl groups from the air. The most important of them is lignin, contents of plant fibres influences its structure, properties and morphology. The distinct cells of hard plant fibres are bonded together by lignin, acting like a cementing material. The cellulose molecules of each fibre differ in their degree of polymerization and consequently, the fibre is a complex mixture of polymer homologue $(C_6H_{10}O_5)_n$[19-21].

The main goal of the present work is to fabricate new class of epoxy based composites reinforced with randomly oriented short sisal fibers and determine their vibration characteristics like natural frequency and damping coefficient. The long length fibers were first cleaned to remove the dust and other particles so as to use the fibers for further treatments. The fibers were cut to a length of 200mm so as to make the further treatments easy. Alkali treatment is done using 5% NaOH in order to enhance the adhesion property of the fiber with epoxy resin. It was also important to evaluate the influence of the fiber parameters such as fiber loading on the mechanical behavior and vibration characteristics of the composites and to analyze the moisture absorption and moisture content.

2. EXPERIMENTAL PROCEDURE

Fibers required for the testing were obtained from a small scale rope making industry in Tayakanahalli, a village in Chitradurga district, Karnataka, India. The long length fibers were first cleaned to remove the dust and other particles. The cleaned fibers were cut to a length of 200mm so as to make the further treatments easy. Alkali treatment is done using 5% NaOH in order to enhance the adhesion property of the fiber with epoxy resin. First the fibers were soaked in NaOH solution for 48 hrs at room temperature and then the fibers are washed in distilled water to remove the traces of NaOH after treatment. The short sisal fibers are mixed with epoxy resin by simple mechanical stirring and the mixture was poured into

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various moulds, keeping in view the requirements of various testing conditions and characterization standards. The entrapped air bubbles (if any) were removed carefully with a sliding roller and the mould was closed for curing at a temperature of 30°C for 24 hours. The specimens were cut as per dimensions suggested by ASTM standards, after curing. Specimens were prepared according to ASTM D5229-D5229M standard test methods [22] for composites. The specimens were initially weighed and noted, and after that they were weighed daily for 7 days. The moisture absorption capacity of the sisal fibers reinforced epoxy composites was determined. The samples used in the test are shown in Figure 1 . Test has been carried out for 6 days in order to determine the water absorption capacity of the composite. Initially the weights of the specimens were noted down. After that specimens were kept in water as shown in the Figure 1 . They were weighed on daily basis. Subsequent values are recorded.

In order to study the influence of sisal fiber, composites were prepared for different composition by varying the fiber and epoxy ratio. The percentage of sisal fiber was varied from 4% to 10% in steps of 2%. Similarly epoxy content is varied from 96% to 90% in steps of 2%. We have prepared the samples using weight fraction method. Different compositions are named as S1 to S4 as shown in the Table 1. In this process hardener composition is kept constant.

3. RESULTS AND DISCUSSION

3.1 Moisture Absorption Test

Test has been carried out for six days in order to determine the water absorption capacity of the composite. Initially the weights of the specimens were noted down. After that specimens were kept in water the weight versus days has been plotted as shown in Figure 2. and it is observed that maximum deviation have occurred in case of S1 sample. Other samples relatively less absorption of moisture. The reason behind this may be due to cellulose content and fiber resin interface.

3.2 Moisture Content Test

According to ASTM D5229 / D5229M standards for composites, the specimens were prepared for Thermo gravimetric method (shown in Fig. 3). The absorbed Moisture content of prepared samples is measured from the weight loss of prepared samples when the samples are heated. The sample weight is taken prior to heating and again after reaching a steady-state weight of the samples was recorded after drying. Here test is conducted by initially recording the weight of the specimen. Then all the specimens were kept simultaneously in Oven (Temperature 100°C ± 1 °C). The weights of the specimens were recorded on hourly basis. The change of moisture content is calculated and is found to be 0.30% which is well within limit as inferred from earlier literature and tabulated in Table.3.

Table.1 Specimens based on different fiber loading.

Composite type	Composition
S1	Epoxy (90 wt%), Sisal fiber(10 wt%) and Hardener (10 wt% of Epoxy).
S2	Epoxy (92 wt%), Sisal fiber(8 wt%) and Hardener (10 wt% of Epoxy).
S3	Epoxy (94 wt%), Sisal fiber(6 wt%) and Hardener (10 wt% of Epoxy).
S4	Epoxy (96 wt%), Sisal fiber(4 wt%) and Hardener (10 wt% of Epoxy).

Fig. 1 Test Specimen used for Moisture Absorption

Table .2 Variation of weight of the specimen with days

Composition	Weight (gms)						
	Initial	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
S1	30.00	29.79	30.06	30.28	30.32	30.10	30.80
S2	26.28	26.02	26.25	26.33	26.24	26.17	26.18
S3	28.02	27.86	28.08	28.13	28.07	28.00	28.00
S4	26.10	25.98	26.10	26.58	26.44	26.26	26.22

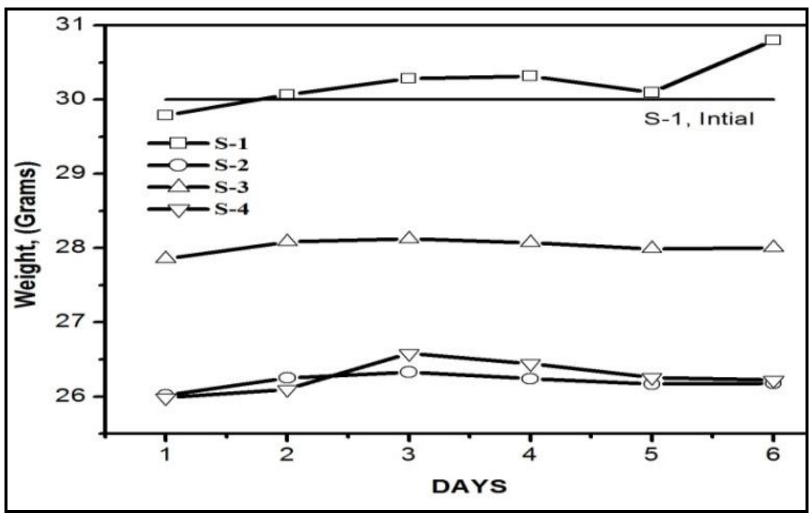

Fig. 2 Variation of Weight of Specimen with days.

Fig. 3 Moisture content specimen kept in Owen.

Table 3: Variation of weight of the specimen with hours.

Composition	Weight (gms)				
	Initial	1st Hour	2nd Hour	3rd Hour	4th Hour
S1	27.947	27.903	27.886	27.877	27.864
S2	26.216	26.176	26.165	26.162	26.154
S3	27.240	27.197	27.182	27.178	27.174
S4	25.381	25.344	25.336	25.321	25.323

3.3 Vibration Analysis

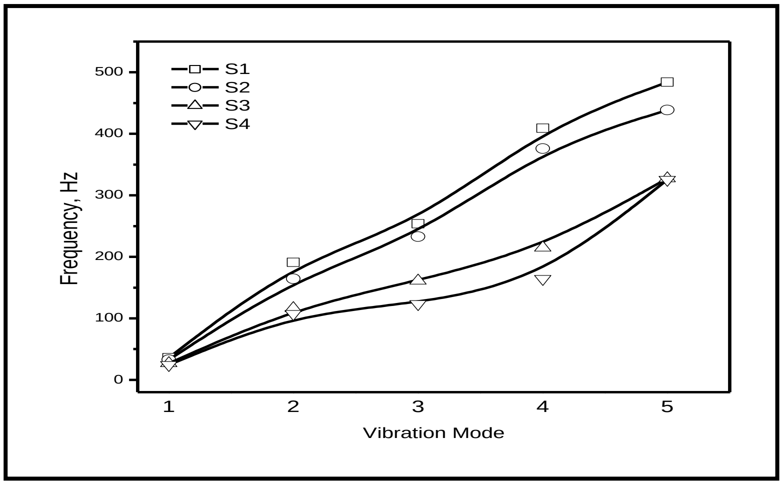

Fig. 4 Variation of Natural frequency for different mode of vibration.

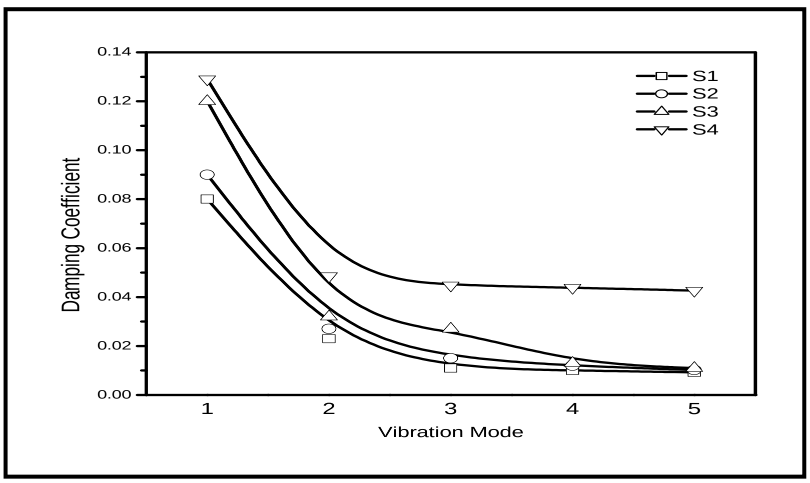

Fig. 5 Variation of damping coefficient for different mode of vibration

Table 4: Natural Frequencies of Different Composition

Composition	Natural Frequencies (Hz)				
	1st	2nd	3rd	4th	5th
S1	35.82	191.04	253.73	408.95	483.9
S2	32.83	164.17	232.83	376.11	438.80
S3	26.86	116.41	161.19	214.92	327.37
S4	24.32	107.46	123.38	164.19	325.37

Table 5: Damping coefficient of Different Composition

Composition	Natural Frequencies (Hz)				
	1st	2nd	3rd	4th	5th
S1	0.08	0.023	0.011	0.010	0.00922
S2	0.09	0.027	0.015	0.0119	0.0102
S3	0.12	0.032	0.027	0.013	0.011
S4	0.129	0.0486	0.0448	0.04388	0.0427

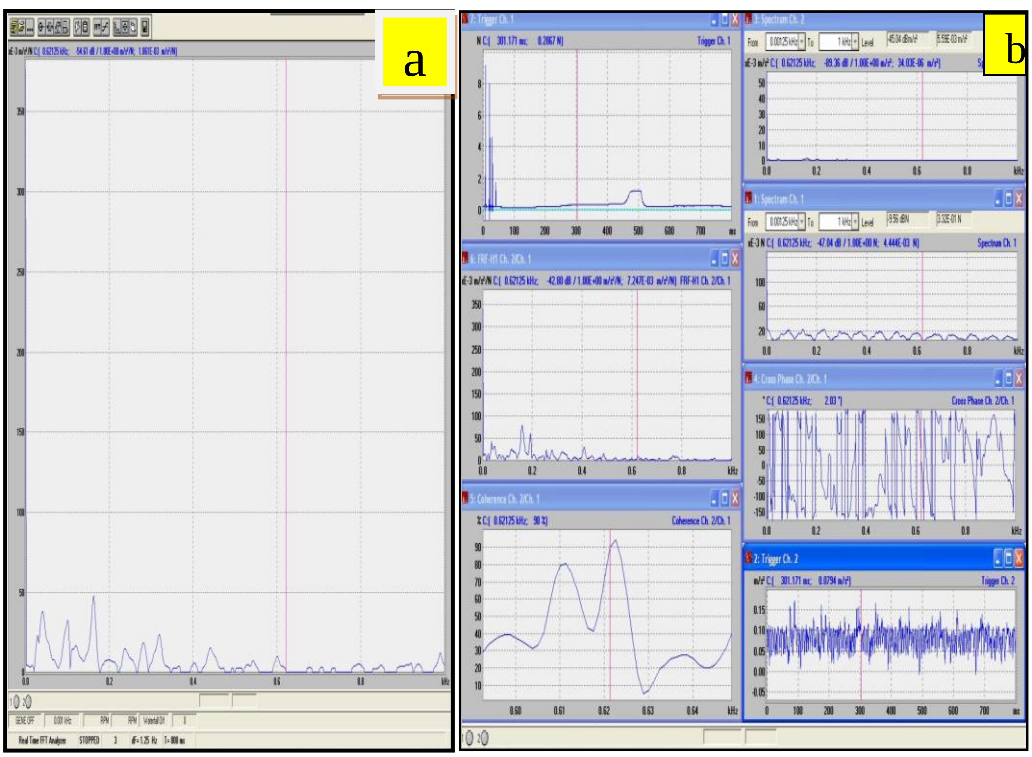

Fig.6 Coherence (a) and Time response (b) of Only Sample S1.

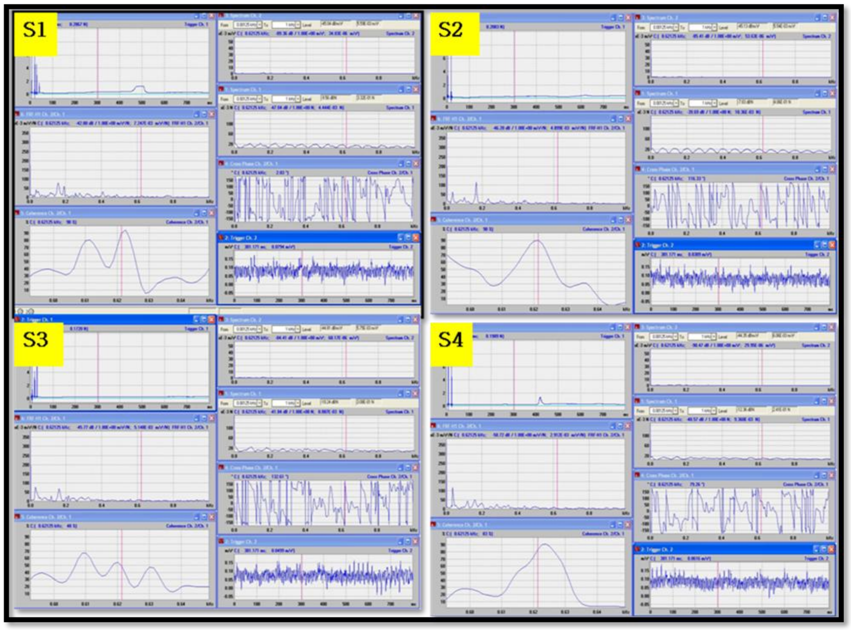

Fig. 7 Coherence and Time responses graph.

The specimen is hung with the help of nylon rope at two points. Single point is marked on the specimen for the free vibration measurements. Excitation hammer and piezoelectric accelerometer are connected to the output channel of FFT analyzer. A series of frequency response measurement are typically made at several excitation points and also a single response point. The specimen is excited at single point using hammer and frequency response function is obtained. Amplitude response also obtained in time domain. The most important measurement that is needed for experimental model analysis is the frequency response function. This is the ratio of output response to the input excitation force. This measurement is typically acquired using FFT analyzer. The values of natural frequencies are directly obtained from the FFT analyzer. Damping coefficients are determined and which is directly obtained from the output of the computer. The details of the graph for various compositions are shown in Figures 6. From the above graphs the values of natural frequencies and damping coefficients are obtained and they are tabulated in Table 4 and 5.

The variation of Natural frequency with respect to Mode of vibration has been plotted as shown in the Figure 4. From Table.4, it is observed that the value of natural frequency increases with increase in fiber loading. Similarly a graph of damping coefficient vs mode of vibration is plotted as shown in the Figure. 5. From the graph (Figure.5) that, with increase in fiber loading, damping coefficient increase with fiber loading. It can be reported that apart from the fiber content (influence of fiber length and fiber orientation), the interface thickness and interface stiffness also play an important role in the damping mechanism [23]. The resonant amplitude of vibration is significantly influenced by modal damping associated with each mode of the structure. Ecumenically, damping associated with fiber reinforced composite structures is higher than conventional metal structures due to the viscoelastic behavior, fiber–matrix interaction and damping due to damage [24-26]. It is also reported that varying the fiber orientation has more significance in producing higher damping than varying fiber aspect ratio and vibration modes [25-26]. In detail, damping for materials with natural fiber is difficult to study due to their chemical constituents; nevertheless it shows good damping characteristics due to its inherent porous nature [26]. In general, higher resin content should lead to higher damping due to its viscoelastic nature [25-26]. Composite material gives opportunity to designer and engineer to increase material efficiency, resulting in cost reduction and better utilization of resources. Composites materials applications are wide in aerospace industries, automobile sector, manufacturing industries etc.

4. CONCLUSION

We have successfully prepared the sisal composites by melt-mixing method, followed by compression molding process. The vibration analysis is carried out in mainly focused on natural frequencies and damping coefficients. With reference to moisture absorption maximum deviation was observed in S1 type specimen. The change of moisture content was found approximately equal to 0.30% which is well within limit. Natural frequency increases with increase in fiber loading and also damping coefficient increase with fiber loading. In general, higher resin content should lead to higher damping due to its viscoelastic nature. Composites materials applications are wide in aerospace industries, automobile sector, manufacturing industries.

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