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VIBRATION AND VISCOELASTIC CHARACTERISTICS OF SISAL FIBER REINFORCED POLYESTER COMPOSITE

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ABSTRACT

This study aims to evaluate the result of experimental investigation carried out on free vibration characteristics and dynamic mechanical analysis over a range of temperature and five different frequencies of short sisal fiber polyester composite. The effect of temperature on the storage modulus (E'), loss modulus (E"), and loss factor or damping efficiency (tanδ) is determined. Composites specimen is fabricated in random fiber orientation using to hand lay-up method by Influence of fiber length (10mm) and weight percentage (5, 10, 15, 20wt. %). Studies revealed that increase in the fiber content will increase the natural frequency (Hz) and storage modulus (E') and the maximum is given by the composites having a fiber loading of 20 wt. % at all temperature ranges. The peak height of loss modulus (E") and damping curves (tan δ) were lowered with respect to the fiber content. The properties were compared with neat polyester. In this work increasing fiber content increases the natural frequency (Hz) and storage modulus (E') of the composite.

KEYWORDS: Natural Fiber (Sisal), Polyester Resin, Free Vibration Testing (FVT) & Dynamic Mechanical Analysis (DMA).

Original Article

INTRODUCTION

In many applications, natural fiber composites are realistic alternative to synthetic fiber composites, since the fibers possess many comparatively recognitions, such as low density, high specific strength, low cost and renewability. The most commonly used plant fibers for polymer reinforcement are sisal, jut, banana, flax, ramie, hemp, etc., which already contribute to various engineering applications. The recitals of amalgamated resources are generally based on their perfunctory distinctiveness, such as tensile, flexural, compression and impact properties table 1. These characteristics are crucial to ascertain the material performance in diversified circumstances. However, natural fiber reinforced composites are not fully investigated for structural engineering applications especially under dynamic loading conditions. Damping is one of the significant factors allied with the vibrant conduct of the materials because of its influence on systems feat, like safety and reliability [1], vibrations elevate high-noise levels, malfunctioning of stress exhaustion, premature wear and hazardous working conditions. Structures can experience too much of pulsation when the forceful loading creates vibrations at normal incidence of the material.

Table 1: Physical and Mechanical Properties of Sisal Fibers

Properties	Sisal
Density(g/cm^3)	1.33-1.45
Tensile strength	510-700
Young's modulus(GPa)	9-38
Moisture absorption %	11
Elongation at break (%)	2.2-2.9

Hence consideration of the whole vibration effect on the materials is very important for the effectual design and use of this composite[2-6]. Free vibration test and Dynamic mechanical analysis (DMA) are important techniques to study the mechanical behavior of polymer composite resources [7-10]. Prevalent revisions have been made on the method of vibration damping in polymers. However, damping mechanisms in FRP materials vary completely from conventional polymers [11-14]. In case of composite materials, the occurrence of fillers or strengthening agents formula multipart interior structures in the material in which the damping behaviors rely not only on properties of individual materials but also on many other features, e.g. volume fraction of fillers table 2, the quality of the interface, loading direction and plasticization of polymer[14-17]. There are various energy indulgence mechanisms in fiber-reinforced composites such as visco-elastic nature of matrix and/or fiber materials [18-20], frictions caused by the slip in the matrix/fiber edges, energy indulgence at clefts and delaminating caused at dented spots, visco-plastic and thermo elastic damping [1].

Table 2: Volumes and Mass Calculation of Sisal Fiber

Sample	Volume (Cm^3)	Mass (g)
A	13.5	17.95
B	27	35.91
C	40.5	53.86
D	54	71.82

MATERIALS AND METHOD

Free Vibration Test (FVT)

Sisal fiber and unsaturated polyester resin are used as reinforcement and matrix. The composites were fabricated with sisal fiber cut to a length of 10mm were evenly arranged in a mold measuring 300mm×300mm×3mm for preparing the samples. Various mass percentage (0, 5, 10, 15 and 20) of sisal fiber were used the preparation of samples. To execute a vigorous test, samples were apprehended as a girder. The open end of each sample was connected to the accelerometer, and vibration was initiated with a rubber hammer shown as figure 1. Four specimens of size 220mm×30mm×3mm were used for vibration assessment and the average value is stated. The vibration acceleration assessed the past record through the data acquisition program. To calculate the damping ratio (ξ) of the cantilever beam from recorded acceleration time histories a logarithmic decrement is used based on the following equation 1.

$$\zeta = \frac{1}{2\pi j} \ln \left(\frac{x_i}{x_{i+j}}\right) \text{------} 1$$

Where x_i is the max out acceleration of the i^{th} peak and x_{i+j} is the max out acceleration of the peak j cycles after i^{th} peak.

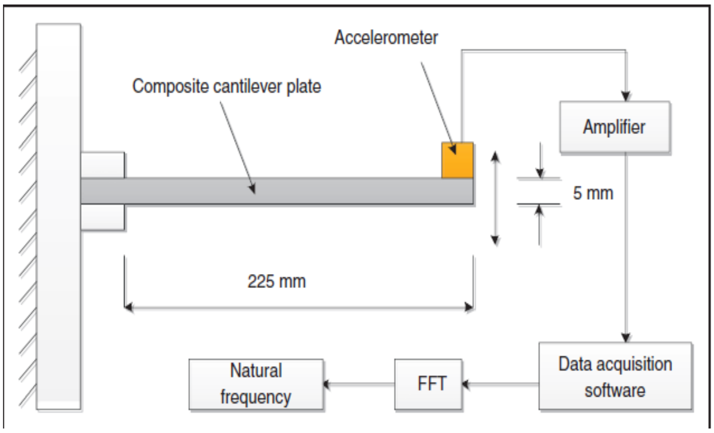

Figure1: Free Vibration Testing System

Dynamic Mechanical Analysis

Dynamic mechanical analysis (DMA) is a potent method for the depiction of the viscoelastic properties of materials. And as these materials are malformed under episodic stress the modulus (stiffness) and damping (energy dissipation) properties of materials are to be constantly premeditated through DMA

Similar procedure can be used to assess a broad array of materials such as thermoplastics, composites, thermo sets, elastomers, films, fibers, coatings and adhesives. Dynamic mechanical testing machine as shown in figure 2.

Viscoelastic Behavior

A polymeric material displays viscoelastic behavior such as both solid-like and liquid-like distinctiveness. The range to which the polymer shows more solid-like or liquid-like properties is reliant to temperature as well as time or frequency.

Phase Angle, (δ)

When revere to time the sample strain reaction delays the input stress wave and this dalai is known as the phase angle, δ. regard

Damping = tan δ = E"/E'

Storage Modulus, E'

The storage modulus refers to the ability of a material to store energy and it is related to the stiffness of the material.

Loss Modulus, E''

The loss modulus correspond the heat dissipated of the samples that gave the materials the molecular motions and this replicate the damping characteristics of the polymer. Due to the viscoelastic nature of several materials, including all polymers, the mechanical properties are functions of temperature as well as time (frequency).

Figure2: Dynamic Mechanical Analyzer

RESULT AND DISCUSSION

Free Vibration Testing (FVT)

The plot of frequency and composite sample is shown in figure 3. The inclusion of fiber into polyester amplified the usual incidence of the samples from (14.43Hz) to approximately (39.66Hz). It exposed that the addition of sisal fiber increases the frequency of the composite which is a constructive indication. The average damping ratio of the composites were estimated and shown as figure 4. The damping ratio mounts with the raise in the inclusion of sisal fiber.

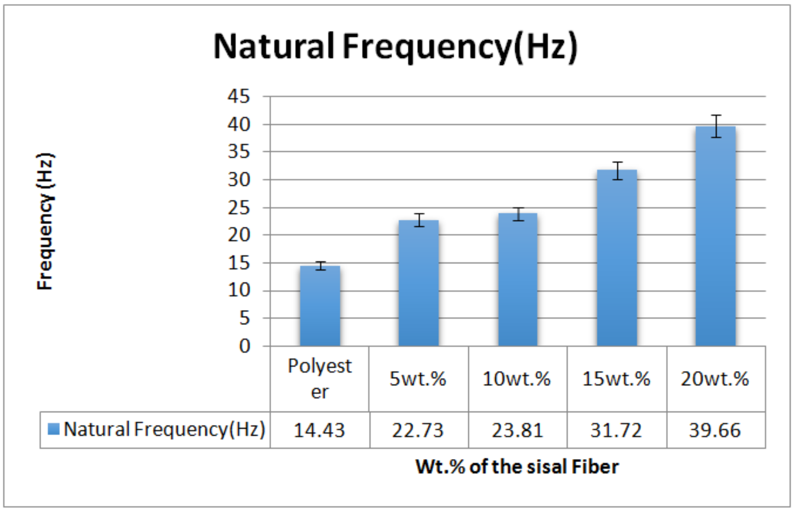

Figure 3: Natural Frequency of Various Composites

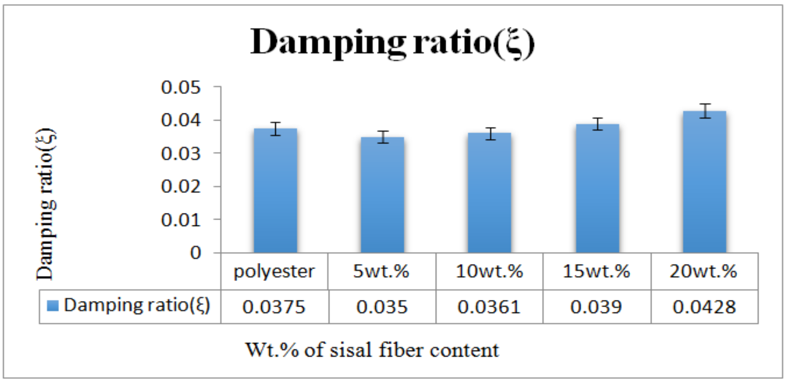

Figure 4: Damping Ratio of Various Composite

Dynamic Mechanical Analysis

Dynamic mechanical analysis is carried out for samples pure polyester, 5wt. %,10wt.%,15wt.%,20wt.% of sisal fiber composite materials obtained results are plotted as graph which gives the storage modulus, loss modulus and damping factor of the composite sample that escalates the temperature and frequency of the materials.

Storage Modulus Vs Temperature Graph With Constant Frequency

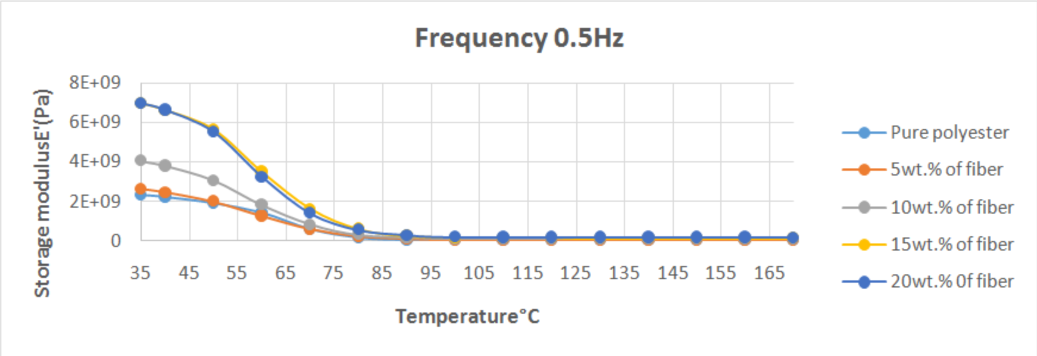

Figure 5(a): Storage Modulus VS.Temp.with Constant Frequency 0.5Hz

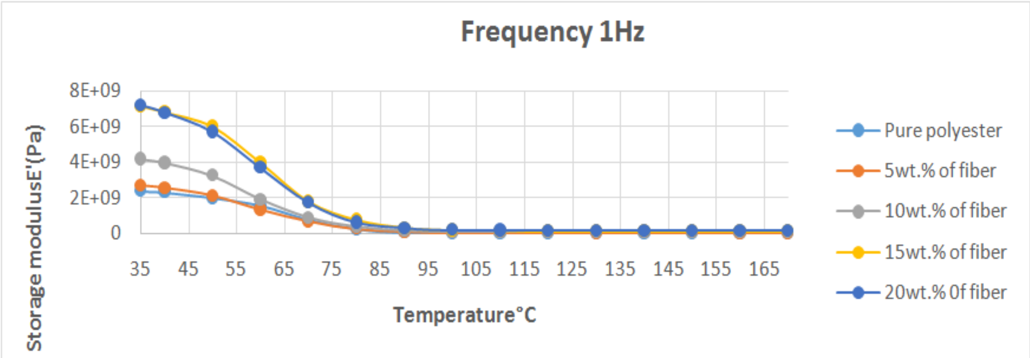

Figure 5(b): Storage Modulus VS.Temp.with Constant Frequency 1Hz

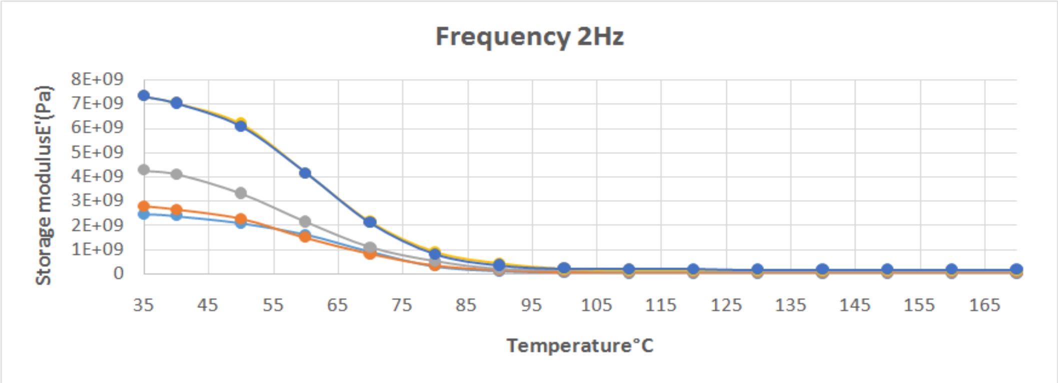

Figure 5(c): Storage modulus VS. Temp. with constant Frequency 2Hz

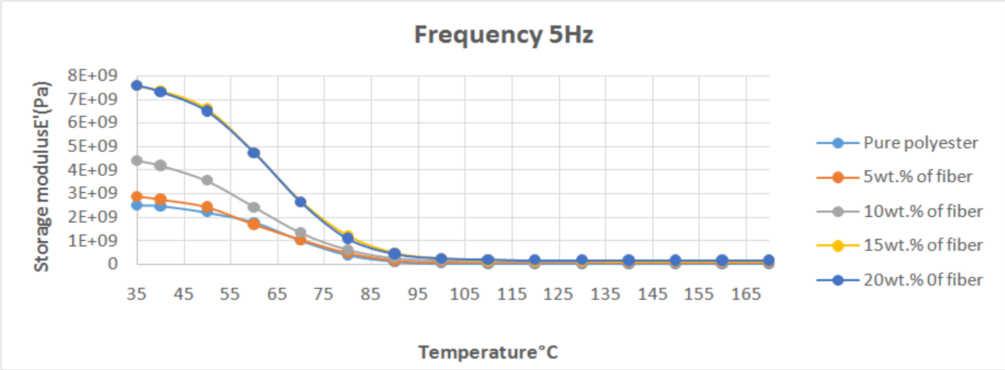

Figure 5(d): Storage Modulus VS. Temp. with Constant Frequency 5Hz

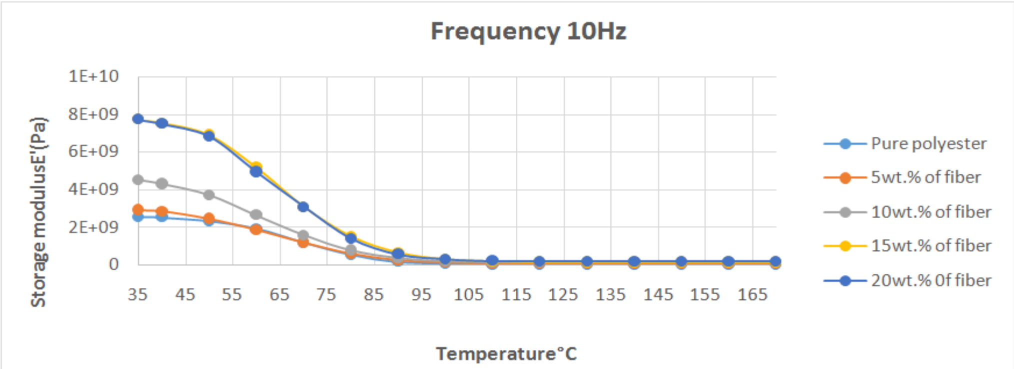

Figure 5(e): Storage Modulus VS. Temp.with Constant Frequency 10HZ

Table 3: Storage Modulus of Materials

Composition	Frequency (Hz)				
	0.5	1	2	5	10
Polyester	2.4GPa	2.5GPa	2.5GPa	2.5GPa	2.6GPa
5wt. % of sisal Fiber	2.5GPa	2.7GPa	2.9GPa	3GPa	3GPa
10wt. % of sisal Fiber	4GPa	4.1GPa	4.1GPa	4.5GPa	4.5GPa
15wt. % of sisal Fiber	7GPa	7.1GPa	7.3GPa	7.5GPa	7.7GPa
20wt. % of sisal Fiber	7GPa	7.1GPa	7.3GPa	7.5GPa	7.7GPa

The Storage modulus values of various composite materials are shown as figure 5(a, b, c, d, e). The value of storage modulus of polyester resin is 2.6E+09Pa and polyester resin with 5wt. %, 10wt.%, 15wt.% and 20wt.% of the sisal fiber values are 3E+09Pa, 4.5E+09Pa,7.7E+09Pa and 7.7E+09Pa respectively table 3. It is found that the maximum value of Storage modulus of 7.8E+09Pa is obtained with the addition of 20wt. % sisal fiber to the composite material.

Loss Modulus VS Temperature Graph with Constant Frequency

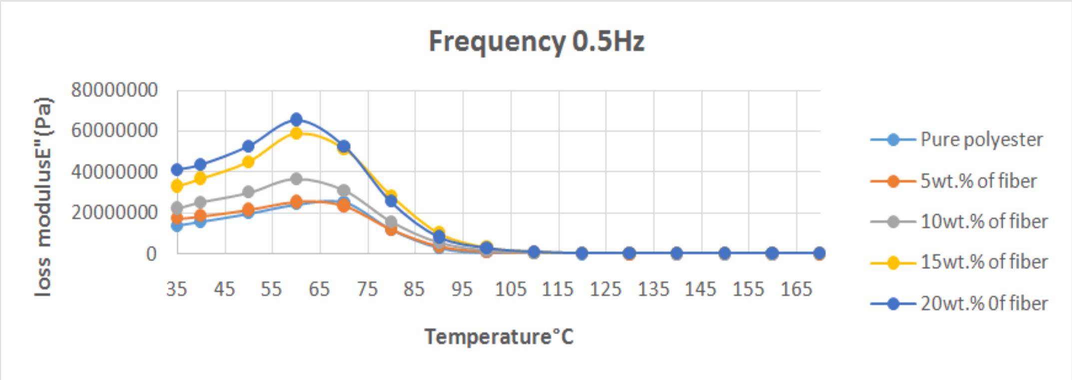

Figure 6(a): Loss Modulus VS Temp. with Constant Frequency 0.5Hz

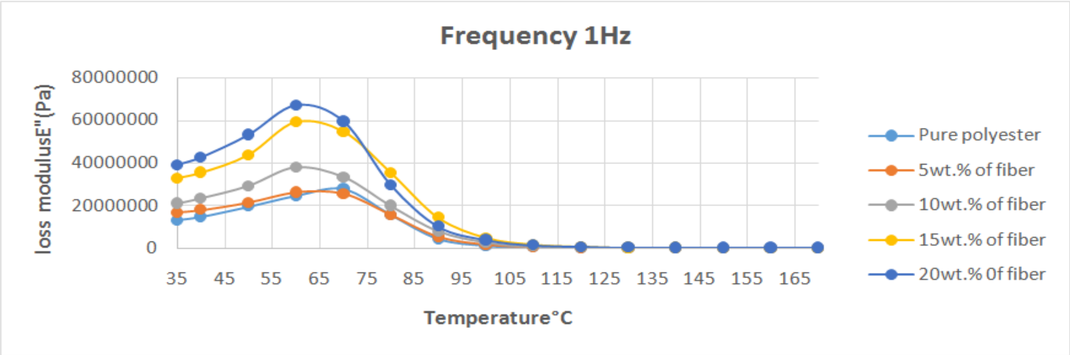

Figure 6(b): Loss Modulus VS Temp. with Constant Frequency 1Hz

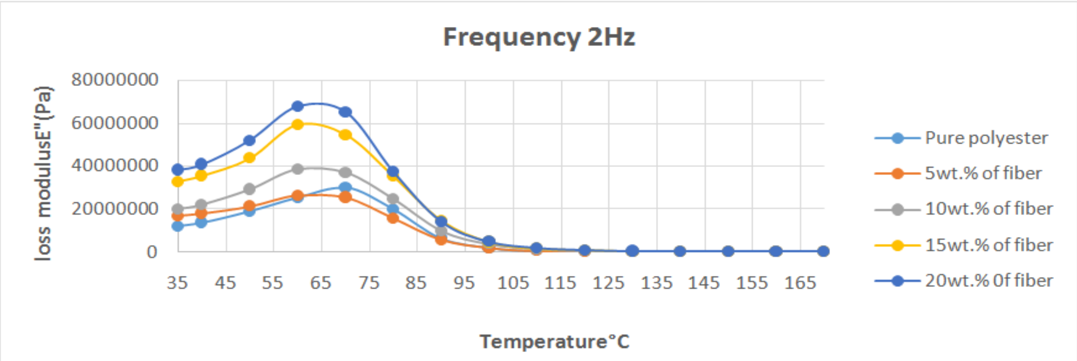

Figure 6(c): Loss Modulus VS Temp. with Constant Frequency 2Hz

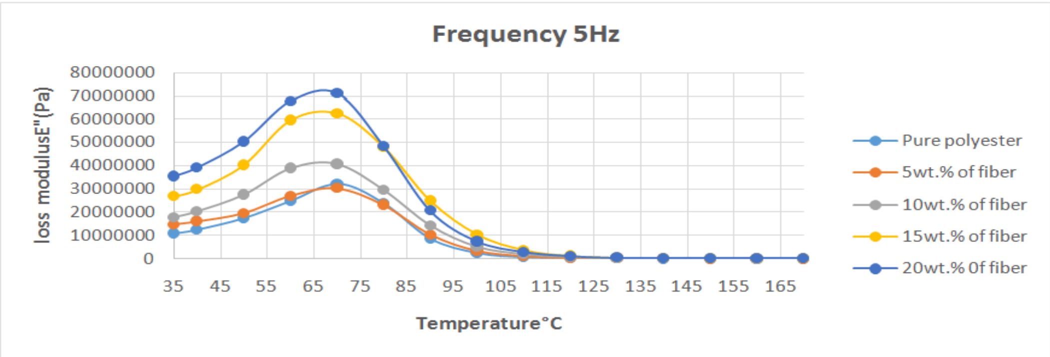

Figure 6(d): Loss Modulus Vs Temp. with Constant Frequency 5Hz

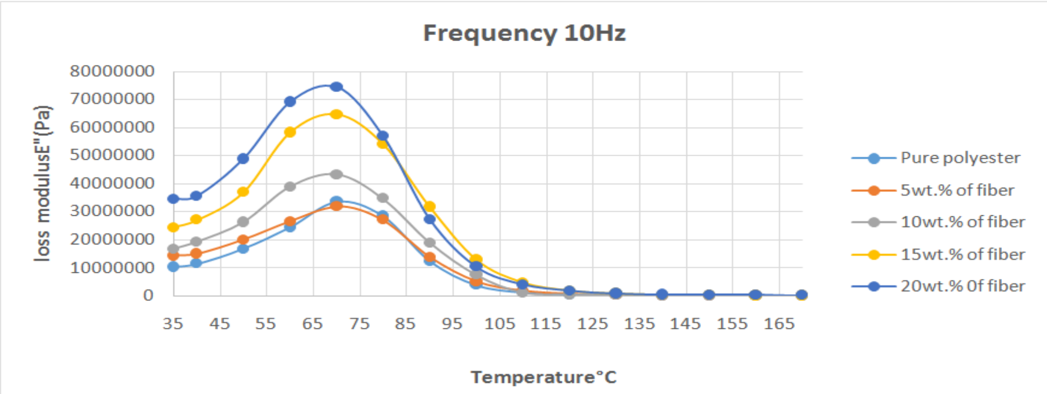

Figure 6(e): Loss Modulus VS Temp. with Constant Frequency 10Hz

Table 4: Loss Modulus of Materials

Composition	Frequency (Hz)				
	0.5	1	2	5	10
Polyester	1.4 E+07 Pa	1.3 E+07 Pa	1.2 E+07 Pa	1 E+07 Pa	1 E+07 Pa
5wt. % of sisal Fiber	1.5 E+07 Pa	1.5 E+07 Pa	1.5 E+07 Pa	1.5 E+07 Pa	1.3 E+07 Pa
10wt. % of sisal Fiber	2.1 E+07 Pa	2 E+07 Pa	2 E+07 Pa	1.8 E+07 Pa	1.4 E+07 Pa
15wt. % of sisal Fiber	3.2 E+07 Pa	3.2 E+07 Pa	3 E+07 Pa	2.7 E+07 Pa	2.5 E+07 Pa
20wt. % of sisal Fiber	4.1 E+07 Pa	3.9 E+07 Pa	3.9 E+07 Pa	3.5 E+07 Pa	3.5 E+07 Pa

The Loss modulus values of various composite materials are shown as figure 6(a, b, c, d, e). The value of loss modulus of polyester resin is 1E+07Pa and polyester resin with 5wt. %, 10wt.%, 15wt.% and 20wt.% of the sisal fiber values are 1.3E+07Pa, 1.4E+07Pa,2.5E+07Pa and 3.5E+07Pa respectively table 4. It is found that the maximum value of loss modulus of 3.5E+07Pa is obtained with the addition of 20wt. % sisal fiber to the composite material.

Damping factor VS Different wt.% of fiber graph with constant temperature (80˚C) varying frequency.

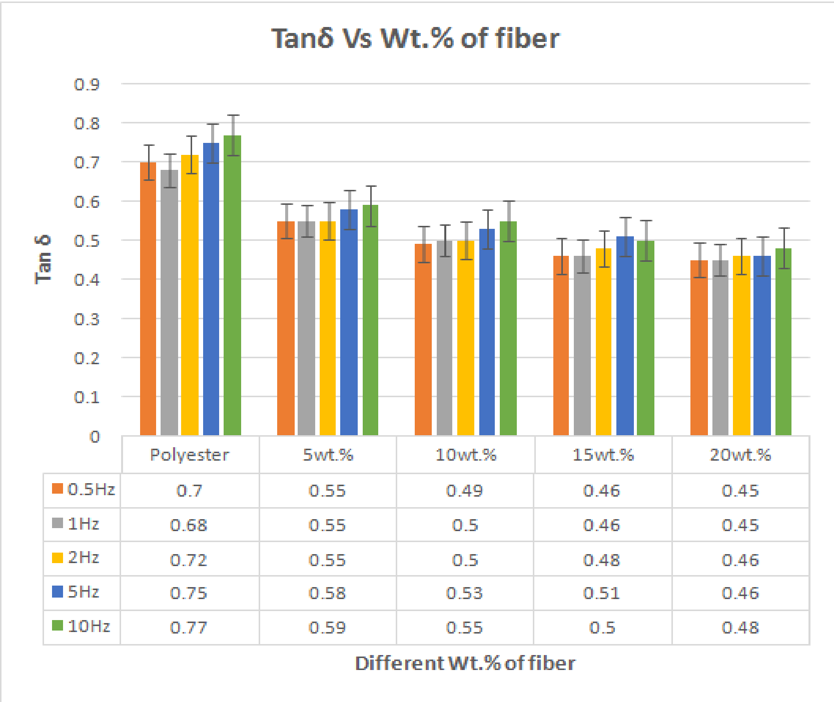

Figure 7: Influence of Weight Percentage on Damping Ratio

Damping Factor values of various composite materials are shown as figure 7. The value of damping factor of polyester resin is 0.77 and polyester resin with 5wt. %, 10wt.%, 15wt.% and 20wt.% of the sisal fiber values are 0.59,0.55,0.5 and 0.48 respectively. It is found that the minimum value of damping factor 0.48 is obtained with the addition of 20wt. %sisal fiber to the composite material.

CONCLUSIONS

In this work, vibration and damping characteristics behavior of short sisal fiber-reinforced polyester composites was inspected by free vibration testing and dynamic mechanical study. It is concluded that the addition of sisal fiber increases the natural frequency (39Hz) and damping ratio (0.0428).It is found that the maximum value of Storage modulus (7.8GPa) and loss modulus of (3.5E+07Pa) are obtained with the addition of 20wt. % sisal fiber to the composite material. It is found that the minimum value of damping factor 0.48 is obtained with the addition of 20wt. % of sisal fiber to the composite material. These results encourage using sisal fiber reinforced composite in vehicles' parts where vibration absorption is of big fright. Also the frequency has adverse effect on the damping property of the composite.

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