VISCOELASTIC PROPERTIES AND FRACTURE TOUGHNESS OF HYBRID POLYMER COMPOSITE USING BANANA/SISAL FIBER

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ABSTRACT

During these days, natural fibers are replacing synthetic fiber as reinforcement in polymer composites. In this investigation banana and sisal fiber are used as reinforcement with epoxy as a matrix. The fracture toughness and Viscoelastic properties of banana/sisal fiber hybrid polymer composites were carried out with special reference to the effect of fiber loading, frequency and temperature. The fracture toughness and energy release rate are found maximum at 30 wt. % of hybrid composite. The results show that on increasing the fiber content up to 30 wt. % the storage modulus and loss modulus increases but damping parameter of hybrid composite decreases.

Keywords- ***Banana Fiber, DMA, Epoxy, Fracture Toughness and Sisal Fiber***

I. INTRODUCTION

To manufacture high performance engineering materials from renewable resources is one of the ambitious goals which are currently being pursued by researchers across the world.These composite materials are replacing conventional materials in so many fields due to their lightweight and easy processing. Natural fibers are being used in place of Synthetic fibers for the preparation of these composites [1-5]. Natural fibers like sisal, jute, coir, oil palm fiber have all been proved to be good reinforcement in thermoset and thermoplastic matrices. Hybrid composites are one of the developing fields in polymer science that are gaining attention for application in various fields, such as building, aeronautical and automotive[6]. The study of bamboo/glass fiber reinforced polymer matrix hybrid composites presents that the reduction in tensile strength and modulus for the hybrid composites is almost half of the un-hybridized composites [7]. Earlier studies [8-11] showed that banana as well as sisal fibers can be used as effective reinforcement in matrix.

Dynamic mechanical test methods have been broadly employed for examining the structures and viscoelastic properties of polymeric materials for determining their relevant stiffness and damping characteristics for various applications. The dynamic properties of polymeric materials are of great practical significance when determined over a range of temperature and frequencies. K. Oksman carried out the investigation dynamic approach of flax fiber and PLA composite [12]. Idicula [10] studied the dynamical mechanical properties of randomly oriented short banana/sisal/polyester hybrid composites and concluded that higher compatibility was obtained hybridizing these fibers, leading to higher stress transfer ability. Dynamic mechanical behavior of jute fiber and HDPE composite was studied by S. Mohanty [13]. Wolfgang [14] has done the dynamic mechanical analysis on the composite of flax and lyocell fiber with epoxy as matrix. The DMA of Hybrid of Ramie and glass fiberwith polyester has been done by the D. Romanzini [15]. B. A Muralidhar [16] carried out the investigation on composite of woven and rib-knitted performs flax yarn with epoxy resin. Fracture toughness of short bamboo fiber reinforced polyester composite was studied by K. J. Wong [17]. A. L. Duigou has investigated the fracture toughness of flax fiber with PLLA biocomposite [18].

In the present study, banana and sisal fiber are selected to hybridize and these fibers are reinforce with epoxy matrix to develop cost-effective and high performance composites. Three types of composite is fabricated using the 10, 20 and 30 wt.% fiber loading which are being represented by BS1,BS2 and BS3 respectively. The influence of fiber content, frequency and temperature on the viscoelastic properties is studied. The rise of T_g value is taken as a measure of the interfacial interaction between them and the effect of fiber content on the T_g values is reported. The T_g is usually interpreted as the peak of the tan δ or the loss modulus curve that is obtained during a dynamic mechanical test conducted at a 1 Hz frequency.

II. EXPERIMENTAL DETAILS

2.1. Materials

Banana fiber is natural fiber of a Musaceae family which is a type of bast fiber, and it is extracted from the bark of banana tree. Sisal is a natural fiber of Agavaceae (Agave) family that yields a stiff fiber, traditionally used in making twine and rope. Both these fibers are purchased from local resource. The matrix used to fabricate the composite is Epoxy AY-105 and the hardenerHY-951 is used with it. The density, tensile strength and young's modulus of epoxy is 1.36 g/cm^3, 70 MPa and 7 GPa respectively. Resin and hardener were purchased from M/s. Bakshi Brothers, Kanpur, India.The properties of banana and sisal fibers are given in Table 1, 2 [19]

TABLE 1 Chemical Properties of Fibers

Chemical Properties	Sisal fiber	Banana fiber
Cellulose %	65	63-64
Hemicellulose %	12	19

Lignin %	9.9	5
Moisture content %	10	10-11
Microfibrillar angle	20^0	11^0
Lumen size(mm)	11	5

TABLE 2 Mechanical Properties of Fibers

Mechanical Properties	**Sisal fiber**	**Banana fiber**
Density (Kg/m^3)	1450	1350
Flexural modulus (GPa)	12.5-17.5	2-5
Tensile strength(MPa)	68	54
Young's modulus (GPa)	3.774	3.487

2.2. Mould Preparation

The fabrication of the composite material was carried out through the hand lay-up technique. Mould used in this work is made of aluminum sheet of 200 mm × 400 mm × 3 mm dimension. The whole surfaces of the mould are coated with remover like wax coating. Two plane plates are used at the top and bottom of the mould to give a plane surface to the composite sheet while pressing. These plates also used to avoid the debris from ingoing into the composite sample during the curing time.

2.3. Fabrication of Composites

First of all the fibers were washed carefully to remove the dust or any unwanted particle from them. After that these fibers were dried. Fibers of different weight percentages (10%, 20% and 30%) were measured in the weighing machine. Epoxy was mixed with hardener in the ratio 10:1. Firstly the moulds are cleaned and wax coating is applied. The mould should be dried before applying epoxy. Then we place a polystyrene sheet in the mould and then we poured some epoxy in the mould to form a layer of it. After that we place the weighted fibers on the epoxy layer uniformly and then we again poured epoxy on the fibers. After epoxy we place again the polystyrene sheet on the mould. Then the composite is compressed for a curing time of 24 h. After the curing process, the sample was post cured in sunlight for 24 hours after removal from mould. Then the test samples were cut to the required sizes as prescribed in the ASTM standards.

2.4 Fracture Toughness

Fracture toughness of composite samples was done on Tinius Olsen Universal Testing Machine. The sample is in a rectangular shape whose dimensions are 56mm × 12.7mm × 3.2mm as per standard of ASTM D5045. The fracture test was carried out at the room temperature with the crosshead speed of 2mm/min. for calculating the fracture toughness of samples following relations is used:

X= a / W

Fracture toughness, $K_Q = \left(\frac{P_{max}}{BW^{1/2}}\right)$ f(x),

$$f(x) = \frac{6x^{1/2}[1.99 - x(1-x)(2.15 - 3.93x + 2.7x^2)]}{(1+2x)(1-x)^{3/2}}$$

Where, P_{max} is the load, B is the specimen thickness, W is the width of specimen, 'a' is the crack length.

Strain energy release rate, $G_Q = U/(BW\phi)$,

And, $U = P_{max}(u_Q - u_i)/2$,

Where, ϕ is the energy calibration factor, u_Q is displacement of the un-notched sample , u_i is the average displacement of samples.

2.5 Dynamic Mechanical Analysis

The viscoelastic properties of composite were studied by using the dynamic mechanical analyzer (Seiko Model DMS 6100). The viscoelastic properties of hybrid banana/ sisal fiber reinforced epoxy composites was determined in 3 point bending as a function of temperature.The composites were cut into samples having dimensions of 50 mm ×13 mm × 3 mm according to ASTM D 5023. Experiments are carried out in the temperature range of 20–200 °C at 1 Hz frequency. The storage modulus, loss modulus and mechanical damping factor (Tan δ) of the specimen were measured and their graphs are plotted as a function of temperature.

III. RESULTS AND DISCUSSION

3.1 Fracture Toughness

The results for fracture toughness of samples are shown in the figure 1. It is found that fracture toughness of sample BS3 is better than other samples due to strong adhesion between fiber and polymer matrix and minimum possibility of providing voids in the composite. The fracture toughness increases when the fiber loading is increases in the composite samples. The same is the case with the strain energy release rate of composite. The strain energy release rate of composite seems to increase with the increase in fiber content. This can be explained as the strong adhesion between fiber and polymer matrix which also gives less possibility of voids in the composite.

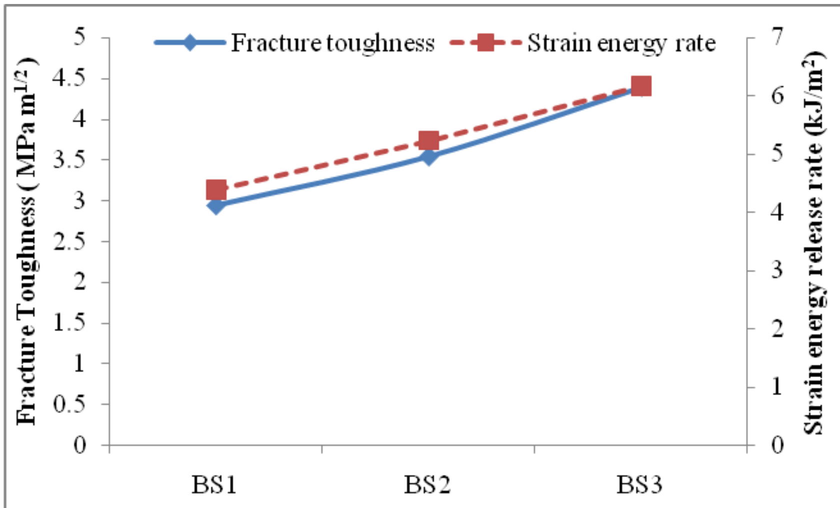

Figure1 Fracture Toughness and Strain Energy Release Rate of Hybrid Composite

3.2 Dynamic Mechanical Testing

Viscoelastic properties of fiber reinforced composites depend on the nature of the matrix material and the distribution and orientation of the reinforcing fibers, the nature of the fiber–matrix interfaces. The DMA were performed on the composite samples in order to determine its glass transition temperature T_g, which marks the transition from a glassy state to a rubbery solid state, and is associated with a considerable reduction of the mechanical properties.

Storage Modulus

The variation of the storage modulus as a function of temperature at 1 Hz frequencies, are shown in the Fig. below. The graph shows that the storage modulus is increasing on increasing the fiber contents in composite. This is attributed to the improved interfacial adhesion between fibers and matrix, which allowed stress transfer from the matrix to the fiber. The storage modulus is observed to decrease with temperature also. Incorporation of fibers hybrid imparts stiffness, but on increasing temperature the stiffness decreases. The results show that when the temperature is increases the samples gives poor strength. BS3 sample gives the good results and has high storage modulus.

Loss Modulus

The variation of the loss modulus as a function of temperature at 1 Hz frequencies, are shown in the Fig. below. For the polymer system the dynamic glass transition temperature (T_g) is defined as the peak of either loss modulus or tan delta. The graph show that with the incorporation of fiber the peak of loss modulus is increasing. There is shifting of glass transition temperature from 75℃ to 81℃ as the fiber content is increased. This shifting of T_g is due to decrease in mobility of matrix with the increase in fiber content. The loss modulus indicates the energy dissipation as heat per sinusoidal formation. Here, BS3 sample has high loss modulus value as compare to others which means it dissipates more energy.

Tan delta

The effect of mechanical loss factor (tan delta) or damping on composite sample as a function of temperature is shown in the graph below. The peak of tan δ curve is occurs in glass transition region, where composite changes from rigid to more elastic state due to movement of molecules in polymer structure. With the incorporation of fibers the tan δ peak is lowered as expected. This is due to the decrease in weight fraction of the matrix by the incorporation of stiff fibers which cause restriction in the movement of polymer molecules. When the fiber concentration is lower, the packing of the fibers behaves inefficiently in the composite, leading to matrix rich region, and consequently easier failure of the bonding at the interfacial region. This can be seen in case of BS2 and BS3 whose value decreases, which shows that there is good interfacial adhesion in between fibers and matrix. There is shifting of glass transition temperature from 80℃ in BS1 to 90℃ in BS3 sample. The tan δ peak of BS3 sample is very low as compare to others. Effective stress transfer and interfacial interaction takes place between the fiber and matrix at this fiber loading.

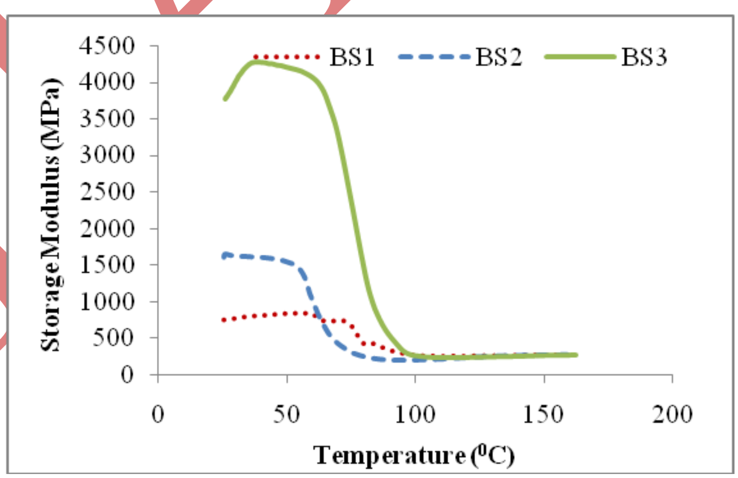

Figure 2 Variation of Storage Modulus With Temperature Of Hybrid Composite

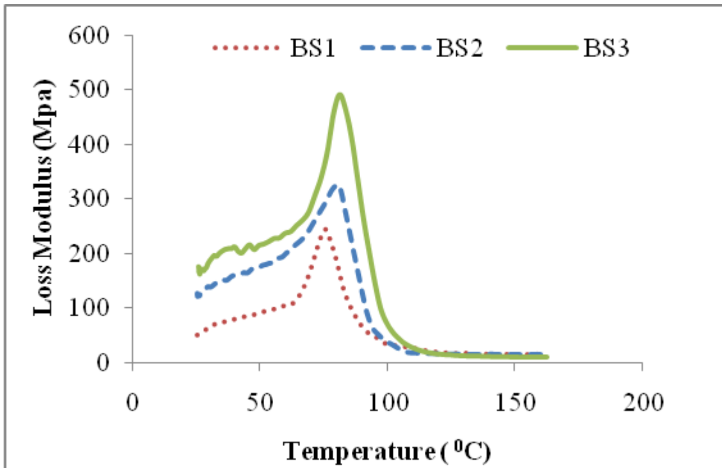

Figure 3 Variation of Loss Modulus with Temperature of Hybrid Composite

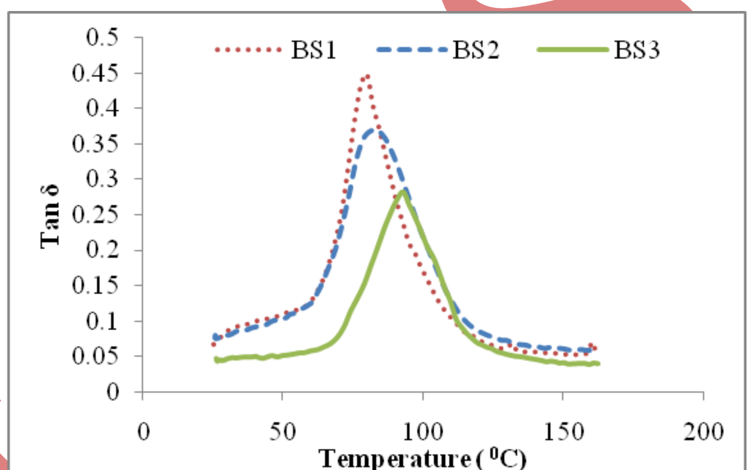

Figure 4 Variation of tan δ with Temperature of Hybrid Composite

IV. CONCLUSION

In this investigation, the effect of hybridization of sisal fiber with the banana fiber for fracture toughness and Dynamic mechanical analysis were studied. Results show that fracture toughness and strain energy release rate of BS3 sample are found 4.39 $MPam^{1/2}$ and6.17 kJ/m^2 respectively. This is due to the strong adhesion between fiber and matrix at 30 wt. % fiber loading.BS3 shows higher storage modulus, stiffness and loss modulus but low damping parameter. BS3 provides better stiffness and storage modulus due to high modulus of elasticity and proper adhesion between fiber and matrix. The Tan δ curve of samples shows that with the incorporation of fibers the tan δ peak is lowered. BS3 has very low peak of curve and has high glass transition temperature of 90℃ which give the effective stress transfer and interfacial interaction between fiber and matrix in that sample.

V. ACKNOWLEDGEMENT

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