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# Dynamic Mechanical Analysis of Palm Fruit Fiber with Palm Leaf Stalk Fiber Reinforced Epoxy Hybrid Composite

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**ABSTRACT:** Dynamic mechanical analysis (DMA) is a useful method that complements the information provided by the more traditional thermal analysis techniques. The dynamic parameters such as storage modulus ( $E'$ ), loss modulus ( $E''$ ), and damping factor ( $\tan \delta$ ) are temperature dependent and provide information about interfacial bonding between the reinforced fiber and polymer matrix of composite material. The present study deals with the effects of natural fibers on visco-elastic properties of natural fiber polymer composites using dynamic mechanical analysis. Composites of epoxy and Palmyra palm leaf stalk with Borassus fruit natural fibers were prepared at 25%, 30% and 35% (by weight) fiber content levels. Specimens for dynamic mechanical analysis tests samples were prepared by compression molding process. Frequency of the oscillations was fixed at 1 Hz and the strain amplitude was 0.1%, which was well within the linear viscoelastic region. Storage modulus, loss modulus, and mechanical loss factor were collected during the test and were plotted versus temperature. An increase in storage and loss moduli and a decrease in the mechanical loss factor were observed for all composites indicating more elastic behavior of the composites. Changes in phase transition temperatures were monitored and possible causes were discussed.

**KEYWORDS:** Palmyra palm leaf stalk fiber, Borassus fruit fiber, Compression molding process; Hybrid composites; Dynamic mechanical analysis.

## I. INTRODUCTION

### 1.1 Objective and Motivation

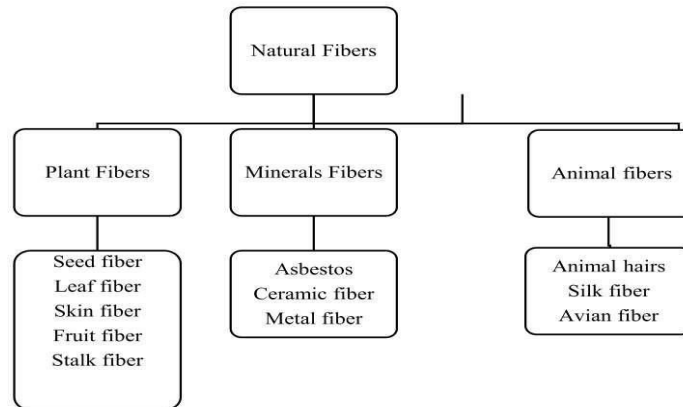
Natural fiber-reinforced polymer composites (NFRP) as eco-friendly and sustainable materials were receiving attention from researchers because their manufacturing and disposal have a small load on the environment other than the synthetic polymer composites. These composites are potentially used in medical devices and various engineering applications, due to some unique characteristics, such as bio-compatibility, high specific strength, low thermal conductivity, and Biodegradability.

In a modern technology, natural fibers have received more scope and can be used in many applications that replace synthetic fibers. Compared with synthetic fibers, natural fibers have some advantages, i.e., light weight, low cost, renewability, etc. Though natural fiber reinforced polymer composites are attractive in their mechanical characteristics so it can be used in automobiles, construction, and biomedicine due to their relatively high specific strength, biocompatibility and biodegradability. The large number of natural fibers available in the global agricultural market is of great significance for improving health, food sustainability with secured provision and poverty removal.

### 1.2 Natural Fiber

Natural fibers are mainly classified as shown in figure 1.1. The demand for environmental awareness, preserving nature and to be beneficial for societal economics has attracted the attention of many researchers to examine the potential usage of natural fibers. The largest advantages of using natural fibers in composites are the lower cost of materials, their sustainability and density. Natural fibers can cost materials. They are also easy to grow and have the potential to be a cash crop for local farmers. Natural fibers are also significantly lighter than glass, with a density of 1.15–1.50

g/cm<sup>3</sup> versus 2.4 g/cm<sup>3</sup> for E-glass natural and synthetic fiber reinforced polymer composites have remarkable mechanical, damping, anticorrosion and durability properties. Composites are employed as structural materials in a variety of industries, including marine, aircraft and construction.



**Fig1.1**Typesofnaturalfiber

### 1.2.1 Animal Fiber

Animal fiber is a natural fiber that is obtained from animals. It is made from different sources of proteins like wool, mohair, silk, alpaca, angora. In general, animal-based fibers such as silk, wool is used as reinforcements for green composites. The properties like surface toughness, high aspect ratio, flexibility, less hydrophilicity give the advantage to animal fiber for practical use compared to other natural fibers.

### 1.2.2 Mineral fiber

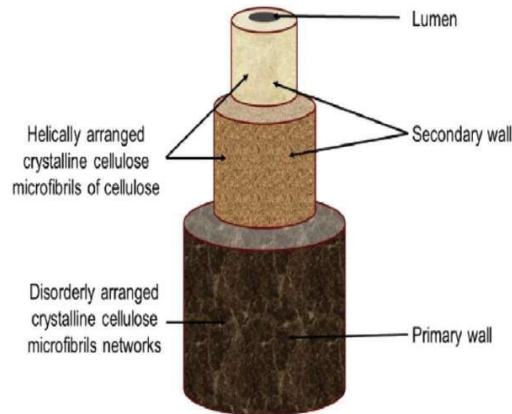
Fiber or slightly altered fiber derived from minerals exists in mineral fibers. They can be classified into the following classes: asbestos, serpentine, and anthophyllite amphiboles. There are six naturally occurring mineral fibers collectively known as Asbestos. However, these fibers lead to the diseases like lung fibrosis, pleural disease, lung cancer, mesothelioma etc. Due to these disadvantages, this mineral-based fiber is rarely used.

### 1.2.3 Plant fiber

The popularly explored natural fiber is a plant fiber, and it is also a very common reinforcement. There are six primary forms of plant fibers: seed fiber, bast fiber, leaf fiber, fruit fiber, straw fiber, etc. Seed fibers are the fibers that are accumulated from the seeds, like coir kapok and cotton. Bast fibers are known as skin fibers. It is acquired from the outer cell layers of the stems. This fiber has more tensile strength than any other type of natural fiber. Flax, jute, hemp, ramie, and kenaf are the most common plants from where bast fibers are derived. Leaf fibers are collected from the plant's leaves, such as abaca, sisal, and pineapple.

### 1.3 Composition of natural fiber

Cellulose (alpha-cellulose), hemicellulose, lignin, pectin, and waxes are the principal components of natural fibers. Figure 1.2 shows the schematic representation of the natural plant cell wall. The cell walls of a hollow tube consist of four distinct layers; a primary cell wall, three secondary cellular partitions, and a lumen; which is an open channel inside the center of the microfibril. The cell walls are mainly made of cellulose, hemicelluloses, and lignin. The properties of regular strands of the fiber can differ depending on the source, age, and isolating strategy.



**Fig1.2 Structure of natural fiber composites**

#### 1.4 Palmyra Palmtree

The figure 1.3 shows the Palmyra palm tree. *Borassus flabellifer*, commonly known as double palm, palmyra palm, tala or tall palm, toddy palm, wine palm, or ice apple is native to South Asia (especially in Bangladesh and South India) and Southeast Asia. Palmyra palms are economically useful and widely cultivated, especially in South Asia and Southeast Asia.

#### 1.5 Borassus fruit



**Fig1.3 Palmfruit**

The Figure 1.4 is portrayed the matured borassus fruit. The fruit (palmyra fruit) measures 10cm (3.9in) to 18cm (7.1in) in diameter, has a black husk, and is borne in clusters. The top portion of the fruit must be cut off to reveal the sweet jelly seed sockets, translucent pale-white, similar to that of the lychee but with a milder flavor and no pit. The sweet jelly seed sockets occur in combinations of two, three or four seeds inside the fruit. The jelly part of the fruit is covered with a thin, yellowish-brown skin. These are known to contain watery fluid inside the fleshy white body. The soft orange-yellow mesocarp of the ripe fruit is sugary, dense and edible, rich in vitamins A and C. They also contain a bitter compound called flabelliferins, which are steroid saponins. The conventional way this fruit is eaten is when the outer casing is still unripe while the seeds are eaten as the fruit. But if the entire fruit is left to ripen, the fibrous outer layer of the palm fruits can also be eaten raw, boiled, or roasted. When this happens, the fruit takes a purple-blackish hue and tastes similar to coconut flesh. The skin is also eaten as part of the fruit similar to how mango skins are often consumed along with the fruit.

### 1.6 Leafstalk

The figure 1.5 is shows the leaf stalk of Palmyra palm tree. The petiole of *Borassusflabellifer* is a robust surface which is rounded with an abaxial surface. The leaf stalks and trunks are used as supporting for kutchha houses, pillars, pipes to supply water, window grills and in boats in coastal regions. From the past *Borassusflabellifer* leaves are used for making water tight buckets, hats, fancy boxes and for the strong wiry fiber. The old and matureleaves are used to fashion into twine and for fencing and also used into the soil as organic manure enrichment. Its tough fibers from the forked butt of the petiole have been used for making the brushes and brooms. At present, the fiber which is obtained by scraping young leaves of *Borassusflabellifer*, are used in textiles industries, construction field, andproduction of ropes, shoes and mats. *Borassusflabellifer* is also used for making sticks, supporting beams, roof covering, construction of thatched houses, making furniture's,carpets, baskets, bags and so on.



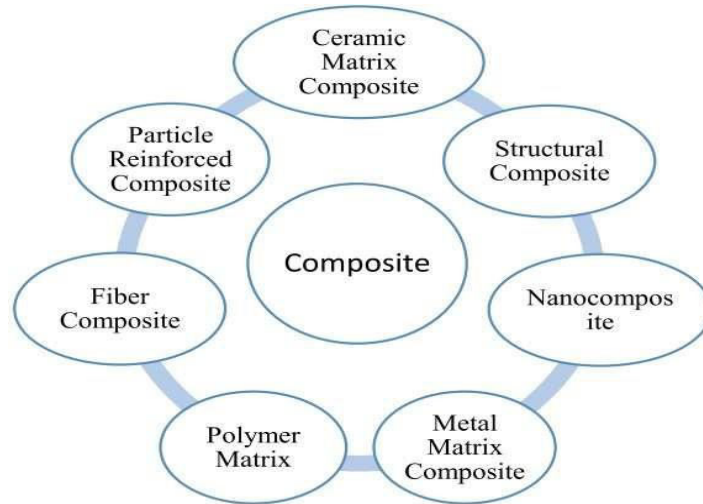
**Fig1.4Palmyrapalmleave stalk**

### 1.7 Chemicaltreatmentofnatural fiber

The hydrophilic natural fiber is incompatible with the hydrophobic matrix ofpolymers as the hydrophilic aspect of the cellulosic fiber affects the fiber-matrix interface. The pre-treatment of natural fibers makes it possible to change chemically or clean the fiber surface. The composite strength of natural fiber, aging, and adhesion of the fiber matrix is enhanced byseveral procedures. Awell-engineered interfacenot onlyincreases thevitalityof the composites; it also offers structural equilibrium. One can control the characteristics and efficiency of a composite by changing the chemical structure of the fiber-matrix interfaces. Specific interfacial properties influence transferring the load from the matrix to the fiber, which helps to minimize the absorption of stress and enhances universal mechanical properties. Fiber surfaces are adjusted with different chemical treatments to increase the efficacy of the interfacial bonding obstacle to the interlocking with the matrix.

### 1.8 Composites

Figure 1.6 portrayed the types of composites. Composite materials are obtained by combining two or more materials to attain exclusive structural characteristics. Within composites, the starting elements preserve their individualities to a certain extent. The concept behind the composites is nothing new and is a century-old trade in human history. The synthetic reinforcements involve carbon, thermoplastics, alumina, boron, silicon carbide, steel, and silicon nitride in general.



**Fig1.5 Different types of Composite Material**

### 1.9 Natural Fiber Reinforced Polymer Composites (NFRPCs)

Natural fiber polymer composites (NFRPC) are made of a polymer matrix implanted within high-strength natural fibers. A matrix is a binder that holds the fiber together and transfers stress between them. It also protects the fiber from environmental and mechanical damage. The chemical compositions of these matrices vary, as do their reactivity with the surface molecules of composite fibers. However, generally, polymers may be subdivided into thermoplastics and thermosets. Among these two groups, the structure of thermoset polymer enables it with high flexibility (effective in customizing target characteristics), strength, and modulus.

### 1.10 Application of Natural fiber-reinforced polymer composite

Numerous advantages make NFRPCs highly desirable in vast and various fields of application. Natural fibers like jute, hemp, kenaf, oil palm, and bamboo reinforced polymer composite have found their implementations in different automotive applications (interior- exterior panels, gas tanks, and bumpers), structural components, packing, and construction/development industry (fundamental boards and building sections). European car manufacturers like German auto companies BMW, Audi Group, Ford, Opel, Volkswagen, Daimler Chrysler, and Mercedes put a lot of effort to upgrade the implementation of NFPCs like cellulose fibers composites in the automotive industry, more particularly in car interiors as well as in exterior auto body components. For instance, the Mercedes Benz A-class model explores coconut fibers, rubber, latex composites for the seats, and the E-class model uses fax-sisal fiber mat reinforced epoxy door panels.

## II. RELATED WORK

**Teli and Jadhav (2017)** studied the influence of NaOH reagent on the mechanical properties of Agave fiber with changing reagent concentrations (i.e., 2, 5, 10, 15 and 20%) for 1 h and found the most extraordinary mechanical properties at 15%.

**Abhiyaan et al. (2017)** have studied the tensile, flexural and impact strength of Calotropis gigantea Fiber reinforced Phenol-Formaldehyde biocomposites. They reported that the inclusion of Calotropis gigantea Fiber into the matrix enhances the mechanical properties of the composite.

**Vijay et al. (2019)** investigated the tensile strength, thermal stability, and surface properties of untreated and NaOH treated TriDax procumbens fibers. They found that there was an increase in cellulose level after NaOH treatment and a decrease in hemicellulose, pectin, and wax, which improved thermal stability, tensile strength, and surface roughness.

**Sanjay et al. (2019)** investigated the hybridization effect of jute, kenaf, and E-glass fiber reinforced hybrid composites

on mechanical properties as a function of varying fiber layer sequences. They observed that incorporating glass fibers with jute and kenaf fiber enhanced the impact and interlaminar shear strength over pure NFRC. Compared to other laminates, the hybrid laminate with glass and kenaf fiber plies on the outside and jute fiber plies on the inside has improved characteristics.

**Kumar et al. (2019)** treated the dried *Borassus* fruit fibers with 4, 8 & 12 % sodium hydroxide solution for 8 h at room temperature. The treated fibers were washed with tap water, neutralized with 2% HCl solution and again washed it and dried in sunlight for 72 h to remove the moisture. Dried fibers were heated at 100° C for 5 h in an oven to remove the moisture.

**Marathe et al. (2019)** treated the *Borassus* fruit fiber powder (53–88 am) with 5% sodium hydroxide solution for 8h to remove the hemicellulose and lignin to improve the crystallinity and made rough surface of the *Borassus* powder which develops the interfacial interaction between the *Borassus* powder and polymer.

### III. METHODOLOGY

#### 3.1 Materials

##### 3.1.1 Extraction of palm fruit fiber

The raw and dried palm fruit fiber is shown in figures 3.1. The matured *Borassus* fruits were collected from Brass's fruit trees and immersed in water for a week and the black skin was separated. The flush which was bonded with the fibers absorb water and the retting of the same started. The flush lost its bonding strength at this stage. Now the fruits were taken out of water and thoroughly washed in running water.



**Fig3.1 Raw Borassus fruit fiber with flush**

During the washing process the fruits were gently pressed for the removal of the retted flush. The fruits were then immersed in water for three days and the process was repeated for the removal of remaining flush. The fibers were taken out and allowed to dry in the shadow for a couple of days. The fibers were then dried in sunlight for half an hour and extracted. The fibers were gently rammmed to remove the unwanted short fibers and dry flush particulates from them. The physical and chemical properties of *Borassus* fruit fiber (BFF)



**Fig3.2 Raw dried Borassus fruit fiber**

Table3.1 Physical and chemical properties of raw Borassus fruit fiber

Properties	
Density( $\text{g/cm}^3$ )	1.26
Average diameter( $\mu\text{m}$ )	203-287
Cellulose(%)	68.8
Hemi-cellulose(%)	14.1
Lignin(%)	5.4
Wax(%)	0.65

### 3.1.2 Extraction of Palmyra palm leaf stalk fiber

The Fibers extraction process of Palmyra palm leaf stalk Fiber (PLF) is illustrated in Figure 3.2 (a-d). The leaf stalk fibers were extracted from the leaf stalks of Palmyra palm tree. The leaf stalks were cut and the thorns at the outer edges were shaved with the help of a sharp edge knife. The skin of the leaf stalks was peeled off and was then cut into strips and it was wetted in water for 20 days. The wetted leaf stalks are then gently hammered with the help of a wooden hammer to split the fiber bundles which are entangled with each other. Then the individual fibers were separated with hand. The fibers had a fleshy substance sticking to the surface which was removed with the help of wet cloth and dried in sunlight to remove the moisture in the fibers.

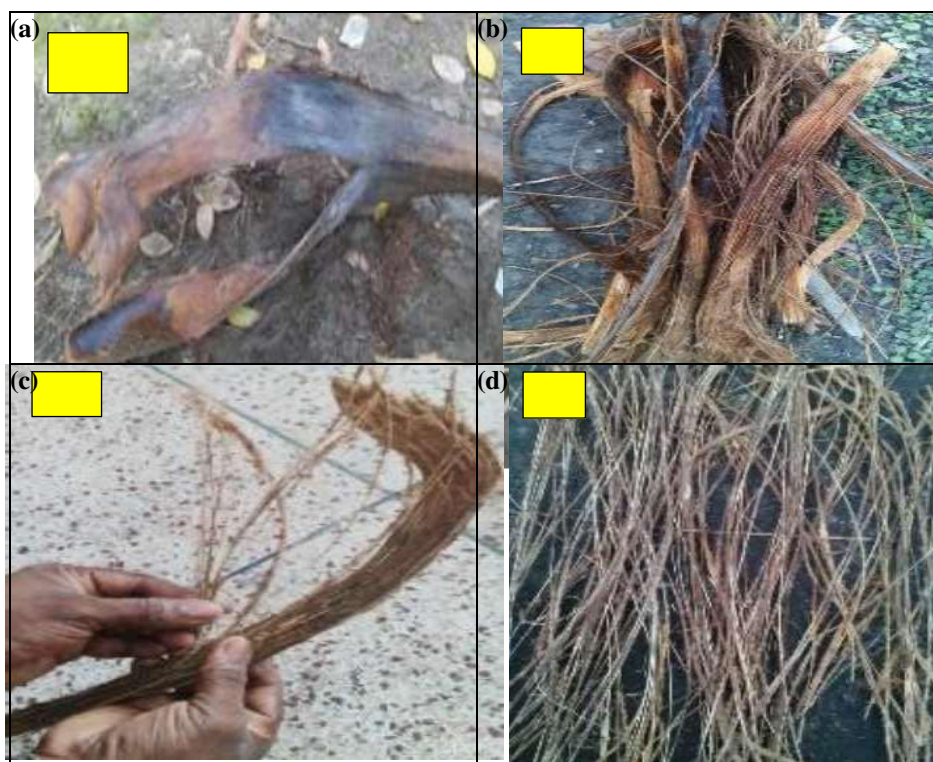


Table3.2 Physical and chemical properties of Leaf stalk fiber

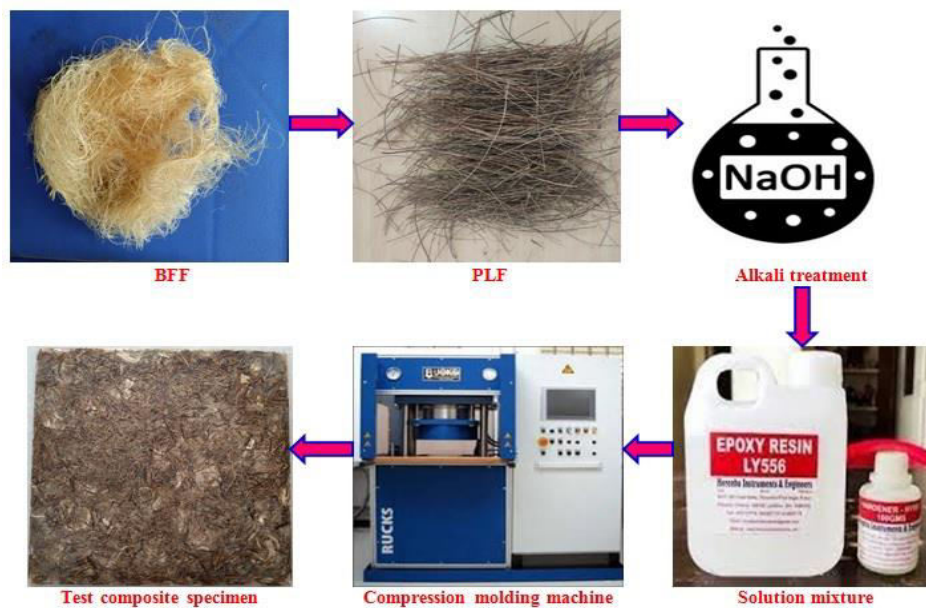
Properties	
Density( $\text{g/cm}^3$ )	1.2
Average diameter( $\mu\text{m}$ )	300-320
Cellulose(%)	58.6



Hemi-cellulose(%)	22.7
Lignin(%)	13.5
Wax(%)	0.36

### 3.1.3 Composites fabrication method

Figure 3.6 is shown the composite fabrication methodology. A rectangular steel mold 290 mm (Length) X 290 mm (Width) X 3 mm (Thickness) was taken for test composites fabrication. The composite fabrication was developed by using compression molding way using a steel mold. The composites were fabricated at a dimension of 290 mm (L) × 290 mm (W) × 3 mm (T). After the molds of required dimensions were prepared, wax was applied to the inner sides of the molds for easy release of the composite without sticking to the mold walls. Then the matrix was prepared by mixing the hardener to epoxy. The epoxy and the hardener ratio were maintained at 10:1. To get well cured and a standard quality specimen, the epoxy and hardener must be mixed smoothly and slowly for approximately 10 min. Initial layer of the mold was filled with the epoxy resin and hardener mixture and then the appropriate quantity of fibers (15 wt.% of BFF + 15 wt. of PLF) was placed such that epoxy mixture completely spread over the fibers. Again epoxy mixture was poured on the fibers mixture. Thus, the starting and ending of the layers were of epoxy resin.



A plastic releasing film was placed on the top of the uncured mixture. Before applying compression, efforts were made to remove all bubbles with roller. Finally, the compression pressure of 5 MPa was applied evenly and cured for one day at room temperature. The same procedure was followed to fabricate the required composite specimens reinforced with untreated and different NaOH concentrated (5%, 10% and 15%) treated fibers mixture. Epoxy with fibers material combinations with their assigned codes were tabulated in Table 3.3. The weight % of developed composites is shown in Table 3.4.

**Table 3.3 Materials combinations and code allocation for composites**

Fabricated composites proportion	Code allocated
NaOH treated BFF+PLF 25%	C1
NaOH treated BFF+PLF 30%	C2
NaOH treated BFF+PLF 35%	C3

Table 3.4 Formulation of the test composites samples

Code assigned	BFF+PLF (wt%)	Epoxy (wt%)
C1	25	75
C2	30	70
C3	35	65

### 3.1.4 Composites testing method

DMA works by applying a sinusoidal deformation to a sample of known geometry. The sample can be subjected by a controlled stress or a controlled strain. For a known stress, the sample will then deform a certain amount. In DMA this is done sinusoidally. How much it deforms is related to its stiffness. A force motor is used to generate the sinusoidal wave and this is transmitted to the sample via a drive shaft. One concern has always been the compliance of this drive shaft and the affect of any stabilizing bearing to hold it in position. A schematic of the analytic train of the DMA 8000, Figure 3.7 shows its innovative design that requires neither springs nor air-bearings to support the drive shaft.

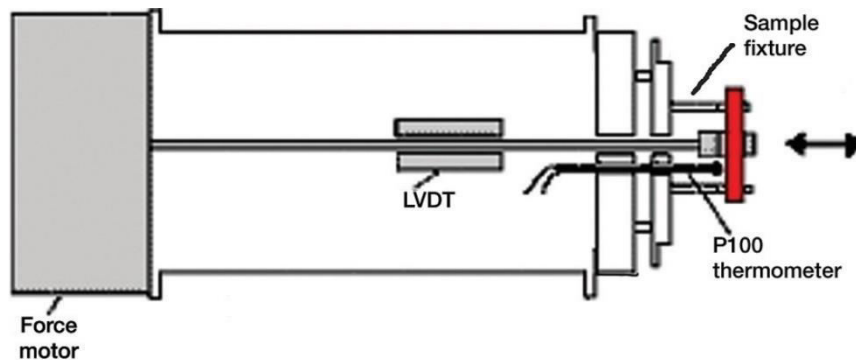


Figure 3.4 Schematic diagram of DMA tester

## IV. CONCLUSION

The static and dynamic mechanical properties of the palm/epoxy laminated composites used in combination with PLSS particles were investigated. Various properties of the hybrid composites including tensile modulus, flexural modulus, and impact strength were increased due to proper mechanical interlocking of the epoxy with the PLSS particles and palm fiber. Micrographs of the fractured tensile, flexural, and impact surfaces of the samples confirmed it. A significant improvement in storage modulus (2045 to 2962 MPa) was observed in the glassy region after incorporating filler into the palm-epoxy composite. A low  $\tan\delta$  value was observed for the EPP0 (unfilled) composite, which indicates strong interfacial adhesion between the fiber and matrix. Filler addition increased the heterogeneity of the composite, as observed from the Cole-Cole plot. Further, PLSS addition increased both the swelling index and weight gain of the palm-epoxy composites. With the increment of PLSS particles in the epoxy resin, the viscosity of the matrix increased. Beyond 15 wt.% of PLSS addition into the epoxy, it was difficult to fabricate the laminates using the hand-lay-up technique. Finally, the PLSS filled palm-epoxy composites could be used for structural applications in the automotive, aerospace, sports and many other industries.

## REFERENCES

1. Abdul Khalil, H. P. S., Jawaid, M., and Abu Bakar, A. (2011). "Woven hybrid composites: Water absorption and thickness swelling behaviors," *Bioresources* 6(2), 1043-1052. DOI: 10.15376/biores.6.2.1043-1052
2. Adak, N. C., Chhetri, S., Kim, N. H., Murmu, N. C., Samanta, P., and Kuala, T. (2018). "Static and dynamic mechanical properties of graphene oxide-incorporated woven carbon fiber/epoxy composite," *J. Mat. Eng. Perform.* 27(3), 1138-1147. DOI: 10.1007/s11665-018-3201-5
3. Ankus, M., Ozkan, N., and Bakir, U. (2018). "Efficient acetylation of Xylan's by exploiting the potassium acetate formed during the alkaline extraction," *J. Polymer. Environ.* 26, 3397-3403. DOI: 10.1007/s10924-018-1221-8.

4. Araujo, R. S., Marques, M. P. V., Oliveria, P. F., and Rezende, C. C. (2018). "Bio- composites based on poly (lactic acid) containing mallow and eucalyptus surface modified natural fibers," *J. Polymer. Environ.* 26(9), 3785-3791. DOI:10.1007/s10924- 018-1253-0
5. ASTM E1131-08 (2008). "Standard test method for compositional analysis by thermogravimetry," ASTM International, West Conshohocken, PA, USA.
6. ASTM B117-03 (2003). "Standard practice for operating salt spray (fog) apparatus," ASTM International, West Conshohocken, PA, USA.
7. Asumani, O. M. L., Reid, R. G., and Paskaramoorthy, R. (2012). "The effects of alkali-silane treatment on the tensile and flexural properties of short fiber non-woven kenaf reinforced polypropylene composites," *Compos. Part A-Eng.* 43, 1431- 1440. DOI: 10.1016/j.compositesa.2012.04.007
8. Atiqah, A., Jawaid, M., Ishak, M. R., and Sapan, S. M. (2017). "Effect of alkali and silane treatments on mechanical and interfacial bonding strength of sugar palm fibers withthermoplasticpolyurethane," *JournalofNaturalFiber* 15,251-261. DOI: 10.1080/15440478.2017.1325427
9. Biswas, S. (2014). "Erosion wear behavior of copper slag filled short bamboo fiber reinforced epoxy composites," *International Journal of Engineering and Technology* 6(2), 91-94. DOI:10.7763/IJET.2014.V6.672
10. Chee, S. S., Jawaid, M., Sultan, M. T. H., Al Othman, O. Y., and Abdullah, L. C. (2019). "Thermomechanical and dynamic mechanical properties of bamboo/woven kenaf mat reinforced epoxy hybrid composites," *Compos. Part-B Eng.* 163, 165-174. DOI: 10.1016/j.compositesb.2018.11.039



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