**DYNAMIC MECHANICAL ANALYSIS**

**ON SHORT JUTE EPOXY COMPOSITE WITH VARYING FIBER LENGTH AND WEIGHT FRACTION**

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**Abstract**

In recent study on the mechanical and thermal properties of natural fiber reinforced composite have been possessed many advantages over the synthetic composite. In this work we have investigate the dynamic mechanical behavior of short jute fiber epoxy composite with the help of Dynamic mechanical analyzer. Where fiber content (10 wt. % and 20 wt. %) and average fiber length (2.5 mm, 12.5 mm and 22.5 mm) both are varying and fabrication has been done with the help of hand lay-up method. The value of storage modulus (E'), loss modulus (E'') and damping (Tan δ) are different at 10 & 20 weight fraction. The value of storage modulus (E') has been increased when weight fraction are increased for each fiber length. Beside it was also observing, at 10 weight fraction the value of glass transition temperature (Tg) has been increase when fiber length are increased in both loss modulus curve and Tan δ curve while at 20 weight fraction the value glass transition temperature (Tg) is decrease when fiber length increase up to 22.5 mm which has shown in loss modulus curve and Tan δ curve.

**Keywords:** Jute fiber, Dynamic Mechanical Analysis (DMA), Hand lay-up Method.

**1 INTRODUCTION**

Natural fiber polymer composites have many advantages over synthetic fiber composite like low density and weight, mechanical performance, renewability, less price etc. In now days, jute fiber are also being used as a reinforcement material for manufacturing purpose in application of automobiles or packaging. Jute fiber have contain better thermal, mechanical and electrical properties on comparison to glass fiber[1-3].The properties of natural fiber depends on the different parameters such as fiber diameter, density, cellulose, ash, wax content etc.[4]. The jute fiber is a cheapest natural fiber and it is used in industrial application because its contain the high production rate. Low manufacturing cost and commercial availability is also an advantage of jute fiber [5]. According to matrix, reinforcement and their adhesion properties the mechanical performance of composites has been investigated [6]. DMA is used for investigate the dynamic mechanical behavior of materials with varying temperature [7]. The analysis has been carried out at a constant frequency under a sinusoidal force. The ratio of loss modulus (E'') and storage modulus (E') is identified as damping (Tan δ). The storage modulus is directly proportional to energy stored in one cycle whereas the loss modulus is directly proportional to dissolute energy in one cycle [8]. The rate of storage modulus reduced when temperature rise which is shown in storage modulus curves. In loss modulus curve & damping curve it is observing the value of loss modulus and damping increases up-to glass transition temperature (Tg) and then decrees [9]. DMA has been performed on the different modes like 3 point bending, 4 point bending etc. depending on the application of material properties. Generally for research purpose 3 point bending modes are used. In case of single or double cantilever mode, combined loading are introduce in the system [10]. The damping properties are decrease when matrix and reinforcement have succeeded high bonding strength in the composite [11].In oil palm fiber reinforced composite (low density of polyethylene bio composite), when fiber content increases then the value of storage modulus (E') and loss modulus (E'') also increases and peak value in Tan δ curve is decreases [12]. In this work DMA of short jute fiber epoxy composite has been studied in terms of storage modulus (E'), loss modulus (E'') and damping (Tan δ) where fiber length and fiber fraction both are varying. Temperature range lies between (25-200 0C) at 1 Hz frequency and 3 point bending mode. On the basis of average fiber length and weight fraction the nomenclature are shown below.

|  |
| --- |
| **Nomenclature**  **J2.5w10** 2.5 mm average fiber length of short jute reinforced epoxy composite at 10 weight fraction.  **J2.5w20**  2.5 mm average fiber length of short jute reinforced epoxy composite at 20 weight fraction  **J12.5w10** 12.5 mm average fiber length of short jute reinforced epoxy composite at 10 weight fraction  **J12.5w20**  12.5 mm average fiber length of short jute reinforced epoxy composite at 20 weight fraction  **J22.5w10**  22.5 mm average fiber length of short jute reinforced epoxy composite at 10 weight fraction  **J22.5w20** 22.5 mm average fiber length of short jute reinforced epoxy composite at 20 weight fraction |

\*All fibers are randomly oriented.

**2 MATERIALS AND METHODS**

**2.1 Materials**

In this project reinforcement material is jute fiber. Epoxy resin (LY556) and hardener (HY551) are used as matrix and curing agent respectively. Raw jute fiber and epoxy/hardener is purchased from local supplier. Epoxy resin are viscous in nature and there viscosity, lap shear and density are 1035mPa, 12.63 MPa and 1.12 g/cm3 respectively at 25 0C. Some important properties of jute fiber are given in table 1 [1].

|  |  |  |
| --- | --- | --- |
| S.No. | Properties | Jute fiber |
| 1. | Density (g/m³) | 1.3 |
| 2. | Elongation at break (%) | 1.5-1.8 |
| 3. | Tensile strength(MPa) | 393-773 |
| 4. | Young’s modulus (GPa) | 26.5 |
| 5. | Cellulose (%) | 61-71 |
| 6. | Lignin (%) | 12-13 |
| 7. | Microfibrillar angle | 80 |
| 8. | Wax | 0.5% |
| 9. | Hemi cellulose | 14-20 |
| 10 | Pectin (%) | 0.2 |
| 11. | Ash (%) | 0.5-2 |

**2.2 Fabrication of composites**

At room temperature the fabrication process of composite sheet has been done with the help of hand lay-up method. Jute fibers are cut in average fiber length of 2.5mm, 12.5mm and 22.5mm and remove there moisture in oven at 80 0C. A mould is made by stainless steel and dimension of mould is 300mm×200mm×3mm is used for casting. A homogeneous mixing are required without gas bubbles in the composite sheet. A 70 kg balance weight is applied on the composite sheet/mould for proper curing for 24 hour. In this work total 6 separate composite sheets are fabricated of short jute fiber epoxy composite. The sample is cut from composite sheet according to the ASTM standard and the specimen dimension is 50mm×13mm×3mm.

**2.3 Dynamic mechanical analysis**

DMA has been are examined on the Seiko instrument DMA 6100 as per ASTM D 5023 standard. On a sinusoidal force at 1 Hz frequency and mode of bending is 3 point, the dynamic mechanical properties has been investigated. The temperature range lies between 20-200 0C with 3 0C/min Heating rate.

**3 Results and discussion**

**3.1 DMA at 10 weight fraction**

**3.1.1 Storage Modulus (E')**

Storage modulus of material is defined the value of young modulus of material. Storage modulus is a function of temperature which is shown in (fig.1). In glassy region the value of storage modulus of composite sample J2.5w10, J12.5w10 and J22.5w10 is found 1177.897 MPa, 1000.62 MPa and 1532.501 MPa respectively while in rubbery region the value of storage modulus is so closed for each composite. It is also observed that composite J22.5w10 has been achieved highest storage modulus at 10 weight fraction.

**Fig.1.** Difference in storage modulus of short jute composites at 10 weight fraction having different fiber length

**3.1.2 Loss Modulus (E'')**

Loss modulus is defined the viscous properties of materials. The Difference in loss modulus is shown in (fig. 2). At 10 weight fraction, the peak value in loss modulus curve is found 153.51 MPa, 109.81 MPa and 176.53 MPa for composite J2.5w10, J12.5w10 and J22.5w10 respectively. In loss modulus curve peak value is shows the glass transition temperature (Tg) for loss modulus. At 10 weight fraction composite J22.5w10 is contain the better thermal stability comparison to other. At 10 weight fraction the values of glass transition temperature (Tg) for loss modulus is given in table 2.

**Fig.2.** Difference in loss modulus of short jute composites at 10 weight fraction having different fiber length

**3.1.3 Tangent Delta**

The damping (Tan δ) has been correlates the viscous and elastic properties of a materials [15].The variation of Tan δ is an also a function of temperature. The glass transition temperature (Tg) is achieved on the peak point of Tan δ curves which is shown in (fig 3). The value of glass transition temperature (Tg) is found at 5.79E-01, 3.47E-01, and 6.52E-01 for composite J2.5w10, J12.5w10 and J22.5w10 respectively in Tan δ curve. In Tan δ curve, composite J22.5w10 is shows the maximum peak which means this composite obtain the better damping property comparing to other composite while composite J12.5w10 has been achieved lowest Tan δ curve but glass transition temperature of this composite is greater than J2.5w10 composite. At 10 weight fraction the values of glass transition temperature (Tg) for Tan δ curve is given in table 2.

**Fig.3.** Difference in Tan δ of short jute composites at 10 weight fraction having different fiber length

**3.2 DMA at 20 weight fraction**

**3.2.1 Storage modulus (E')**

At 20 weight fraction, the variation of storage modulus is also a function of temperature which is shown in (fig. 4). In glassy region the improved value of storage modulus (due to rise in weight fraction) is found 2071.61 MPa, 1872.84 MPa and 2077.41 MPa for composite J2.5w20, J12.5w20 and J22.5w20 respectively. In rubbery region that the value of storage modulus has been so close for each composite while at 10 weight fraction the value of storage modulus are so close for composite J2.5w10 and J12.5w10.

**Fig.4.** Difference in storage modulus of short jute composite at 20 weight fraction having different fiber length

**3.2.2 Loss modulus (E")**

The variation of loss modulus is also a function of temperature at 20 weight fraction which is shown in (fig. 5). with increasing in temperature, the value of loss modulus is found 267.78 MPa, 204.42 MPa and 105.37 MPa for composite J2.5w20, J12.5w20 and J22.5w20 respectively while the maximum glass transition temperature(Tg) is found 63.14 0C for composite J2.5w20. At 20 weight fraction the values of glass transition temperature (Tg) for loss modulus curve is given in table 2.

**Fig.5.** Difference in loss modulus of short jute composite at 20 weight fraction having different fiber length

**3.2.3 Tangent Delta**

The value of *Tan* δ is found 5.69E-01, 5.70E-01 and 5.76E-01 for composite J2.5w20, J12.5w20 and J22.5w20 respectively on peak of *Tan* δ curve which is shown in (fig 6). The highest glass transition temperature (Tg) is achieved for composite J2.5w20 compared to other jute composite. At 20 weight fraction the highest peak is found for composite J22.5w20 which means the damping property of this composite is better than other composite. At 20 weight fraction the values of glass transition temperature (Tg) for *Tan* δ curve is given in table 2.

**Fig.6.** Difference in Tan δ of short jute composites at 10 weight fraction having different fiber length

**Table 2.** Glass transition temperature (Tg) at 10 and 20 weight fraction having loss modulus and Tan δ curve.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Average fiber length (mm) | Glass transition temperature (Tg) at 10 weight fraction in (0C) | |  | Glass transition temperature (Tg) at 20 weight fraction in (0C) | | |
| Loss modulus  curve | Ten delta  curve |  | Loss modulus  curve | | Ten delta  curve |
| 2.5 | 34.895 | 39.55 |  | 62.84 | 71.29 | |
| 12.5 | 63.431 | 67.799 |  | 61.1s2 | 68.38 | |
| 22.5 | 65.761 | 72.16 |  | 60.98 | 44.33 | |

**4** **Conclusions**

On increasing the average fiber length up to 22.5 mm at 10 weight fraction, the value of glass transition temperature (Tg) has been increased in both loss modulus and Tan δ curve and also the value of storage modulus have been also improved. At 20 weight fraction, the value of storage modulus has been improved for all composite but on increasing the fiber length up to 22.5 mm the value of glass transition temperature (Tg) has been decreases in both loss modulus and Tan δ curve.

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