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Dynamic Mechanical Analysis of Jute And Polymer-Based Composite

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Abstract

The Natural fiber-based composites are gaining very much interest in the researchers nowadays. The damping properties of the material play a vital role in dynamic applications. So, a material should possess damping properties if it has to undergo dynamic loading. The composite sheet is prepared by hand layup technique and samples of size according to ASTM standards are cut from the sheet. [1]The Jute-fiberbased composite is prepared for different fiber compositions and varying frequency (1 Hz and 10 Hz) is applied on the composite in this work. The values of storage and loss modulus along with loss factor are obtained by the DMA apparatus. These results were carefully studied and it was found that with the Increasing fiber percentage the values of 'storage modulus' increase. The value of 'loss modulus' also increases but these values do not increase in the same proportion as the storage modulus. The values of 'loss factor' decreases as the fiber percentage increases from zero to 46 %, this is due to decreased mobility of the matrix phase.[2]

With the increasing fiber percentage in the composite sheet, the 'glass transition' temperature starts increasing also. The maximum 'glass transition' temperature obtained is 490C at VF of 46 %.

Keywords: *Jute-fiber, Volume-Fraction (VF), Polymer, Loss-Modulus, Storage-Modulus, Composite, Dynamic Mechanical Analysis.*

1. Introduction

In this contemporary era, Industrial innovation is developing at an exceptionally fast rate and thus there is asurging request and requirement for new materials. Consequently, fiber-filled composites comprise an enormous segment of these new enhanced materials. The decision of the preparing strategy for manufacturing these materials relies upon the prerequisites such as desired properties, cost factor thought, and future application possibilities. The economic significance of composite materials is currently quite distinguished. There are concrete signs that this pertinence will definitely rise in the foreseeable future.[3] Composites are turning into a fundamental piece of the present materials since they offer enormous benefits, for instance, light in weight, corrosion resistance, higher fatigue strength, quicker assembly process, and so forth. Composite materials currently possess a renowned position in the airplane industry since they have shown their usefulness in many applications. They are additionally utilized for some segments in the automotiveand construction industry.[4]

Open consideration is currently being put on the ecologically delicate composite materials produced using natural fillers and viscoelastic materials. Eco-composites are made of naturally available materials that are non-poisonous and biodegradable. They are alluring in light of the fact that they are generally more secure to deal with and work with and ecologically agreeable. The advancement of eco-composite materials has burgeoned fundamentally because of enhancements in the process of innovation and monetary factors.Composites have been explored as a substitute for natural material made components starting from manufacturing craft structures to golf clubs, electronic packaging to medical instrumentation, and space shuttlesto homebuilding. Composites are also generating curiosity

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and interest in students everywhere across the planet. They're seeing everyday applications of composite materials within the industrial market.[4]

Dynamic Mechanical Analysis (DMA) can be simply described as applying an oscillating force to a sample and analyzing the material’s response to that force. It is a thermal analysis technique that is used to characterizing the viscoelastic behavior of materials. It evaluates changes in the test properties resulting because of varying the five test factors: temperature, time, recurrence, power, and strain. The twisting can be applied sinusoidally, in a steady (or step manner), or under a fixed rate. DMA utilizes tests that can be solid, film fiber gel or thick fluid form. Tradable clamps are utilized to permit the estimation of numerous properties, including modulus, damping, creep, stress releasing, and glass change temperature.[5]

Storage modulus (elasticfeedback) and loss modulus (viscousfeedback) of polymers are estimated as an element of temperature or time as the polymer is exposed to an oscillatory force at a controlled (isothermally or programmatically) temperature in a predetermined set of conditions. The Storageand loss modulus iscalculatedfrom the rigidity, damping, and energy-released shown by the composite during the test. Smooth, viscoelastic, elastic and fluid polymers can be tested by DMA, and a few intricacies of the polymer structure can be surmised from the test outcome. DMA is especially helpful for assessing viscoelastic polymers that have mechanical properties, which not only show time and recurrence but also temperature impact.[6]

The experimentation has been done using a Triton dynamic mechanical-thermalanalyzer as shown in Figure 3. The experimental set up has a rugged construction. It consists of machine clamps, a heating chamber, and the measurement chamber.Jute fiber reinforced polymer composite specimen in three-point bending mode is mounted between the clamps at the ends, whereas the sinusoidal cyclic load is applied at its middle.[1]

2. Methodology and Experimental Setup

2.1 Resin and hardener

The resin acts as a binder for the fibers. The strength of the fiber composite depends on the bond between the filler and resin, their percentage in the total composite, and the degree of compactness achieved. For improved properties, the resin content should be such that it can coat the entire filler particles, leaving minimum or no void content.[7]

C-51 resin manufactured by Lapox was used as a structural matrix. It was selected as the matrix material due to its low viscosity (at 250 C); which lies in the range of 1300-1800 MPa-s and density of 1.13-1.16g/cm3[8]. It also has very good processability along with good mechanical performances. The flashpoint of resin C-51 is greater than 190°C, which is quite good compared to other grades of epoxy.

C-51 resin is usually employed in combination with Hardener K-59. This hardener is fairly reactive and hence produces a strongly exothermic reaction. Hardener K-59 is a very low viscosity liquid having a strong ammoniacal odor based on aliphatic polyamine. The characteristics of hardener K-59 are shown in Table 1.

C-51 resin was mixed with hardener K-59 in the ratio of 100:40 by weight.

Table 1. characteristics of hardener K-59

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Properties	Unit	HARDENER K-59
Viscosity at 25^0 C (Hoeppler)	mPa-s	10-20
Flash point	^{0}C	110-120
Specific gravity at 25^0C	g/cm^3	0.97-0.99
Vapour pressure at 25^0 C	mbar	$2X10^{-2}$
Refractive index	---	1.495-1.500
Colour	---	Pale yellow
Minimum Shelf life*	---	2 year

2.2 Fiber

Indian golden woven Jute fiber was selected as the reinforcement. It is of low cost and has a typical composition of α-cellulose 60-63%, hemicellulose 21-24 %, lignin 12-13%, moisture content 40.53% and pectin 0.2-1.5% by weight. In general, the density of jute fiber is 1.46 g/cc with young's modulus of elasticity 26.5 GPA. The fiber sheet was cut into the size of 150mm X 100mm and was reinforced into the epoxy matrix as in sheet form.

2.3 Fabrication of composite

Polymer composite sample sheet with woven jute fiber sheet of different layers was manufactured by using the "compression molding process". The sample sheets were of size 150 x 100 x 2 mm. A mold was used for making a sheet that has impression of 150 x 100 x 2mm. Then the sample of size 50 x 10 x 2 was cut from the sheet for experimentation purpose.

2.4 Fabrication process

For the fabrication of Jute fiber reinforced polymer composite, the required amount of C-51 resin and hardener K-59 were taken and mixed together in the ratio of 100:40 by weight. The mixture was then stirred very slowly to prevent any bubbles formation chances for a prolonged duration. Then woven Jute fiber, 150 x 100 mm by area was spread in the mold cavity.[9]

The resin was first heated up to 50ºC to reduce its viscosity, and then the mixture of hardener and resin was placed inside the mold impression in which fiber was already present in the filament form and the other half of mold plate was placed over it to complete the assembly.[1]

Furthermore, the mold assembly was put in the hot press table and a hydraulic actuator switch was enacted to raise the hot press table and apply the load on the mold assembly. The force of 1.5 psi was applied to the mold assembly. This force squeezes the resin-fiber mixture, due to which this mixture takes the shape of the mold impression. Figure 1 shows the compressed mold assembly.[8]

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Figure 1.

The mold was kept at the same pressure for 6 hours at 100°C for complete cross-linking of monomers of epoxy resin to form a stable composite plate. Then the mold was allowed to cool gradually for 8-9 hours at room temperature so that no hardening effect takes place on the composite sheet due to sudden cooling. After the whole process, mold was opened and the sample was taken out in the form of the consolidated composite sheet.[10]

Figure 2

2.5 Experimental setup and measurement

When designing with any polymer composite, it is very important to know the mechanical properties for understanding its limits and also its applicability. There are several tests that can be done to determine the dynamic mechanical characteristics of viscoelastic composites. Therefore, for characterizing the dynamic properties of Jute fiber-reinforced composite, various kinds of testing were done on the composite samples. The tests performed on Jute fiber reinforced epoxy polymer composites are as follows:[2]

DMA test: for identification of glass transition temperature.

DMA test: for identification of damping properties.

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With these tests, the composite properties were evaluated and the effect of surface modification of Jute Fiber was investigated. The details of the equipment used for the study are discussed below.

2.5.1 Dynamic mechanical analyzer

Dynamic Mechanical Analysis (DMA) can be simply described as applying an oscillating force to a sample and analyzing the material's response to that force. It is a thermal analysis methodologythat is used to characterize the viscoelastic behavior of materials.

The experimentation has been done using a Triton dynamic mechanical thermal analyzer as shown in Figure 3. The experimental set up has a rugged construction. It consists of machine clamps, a heating chamber, and the measurement chamber.Jutefiber reinforced polymer composite specimen in three-point bending mode is mounted between the clamps at the ends, whereas the sinusoidal cyclic load is applied at its middle.[5]

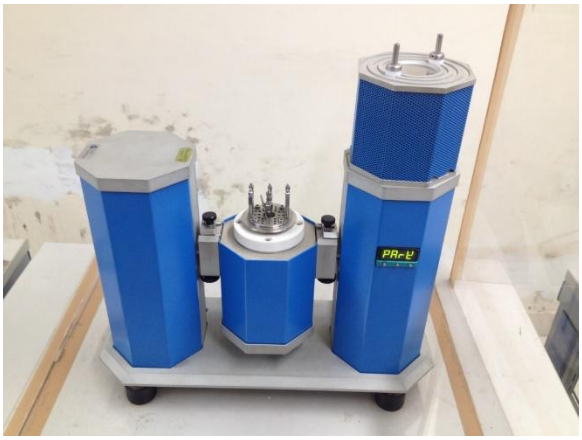

Figure 3. DMA at NIT, Jalandhar

2.5.2 Testing details of DMA:

The damping properties of the jute fiber reinforced epoxy composites were investigated on the DMA instrument. For the testing purpose, the composite plate of size 150 x 100 x 2 mm was further cut into a number of samples of size 50 x 10 x 2 mm. six samples were cut for each configuration of composites. These samples were mounted on machine clamps and the input data were fed into the DMA instrument to investigate the damping properties. Figure 4 shows the image of the samples which were used in testing.

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VF=29% VF=38.83% VF=44.061% VF=46.28%

Figure 4. Fig. of samples used in the DMA test (all dimensions in mm).

3. RESULTS AND DISCUSSION

For the DMA analysis, the below-written composition of samples is to be investigated:

i. Epoxy hardener mixture with Fiber having VF: 29% reinforced composite sample.

ii. Epoxy hardener mixture with Fiber VF: 38.83% reinforced composite sample.

iii. Epoxy hardener mixture with Fiber having VF: 44.061 % reinforced composite sample.

iv. Epoxy hardener mixture Fiber having VF: 46.28% reinforced composite sample.

3.1 DMA test results of composite for the varying temperature at Frequency 1Hz.

For Dynamic mechanical analysis of the sample, the sample size of 50 x 10 x 2 mm was analyzed under the frequency of 1 Hz with a strain rate of 5 microns having ramp rate of value 2.5°C/min. we have selected the three-point bending mode of DMA machine for evaluating the damping properties of composites sample and the results were achieved in the form of Graphs or plots between the modulus and temperature and between damping factor tan (δ) and temperature.

3.1.1 Effect of increase of temperature on storage modulus of FRP samples with varying Fiber content (frequency 1 Hz):

Figure 5 shows the variation in storage modulus against varying temperature for distinct percentages of jute Fiber in the FRP's. From figure 5 it is observed that the storage modulus of FRP increases with an increase in Jute Fiber percentage in FRP Sample. The storage modulus of FRP having VF: 46.28 % in FRP sample has highest value of storage modulus.[11]

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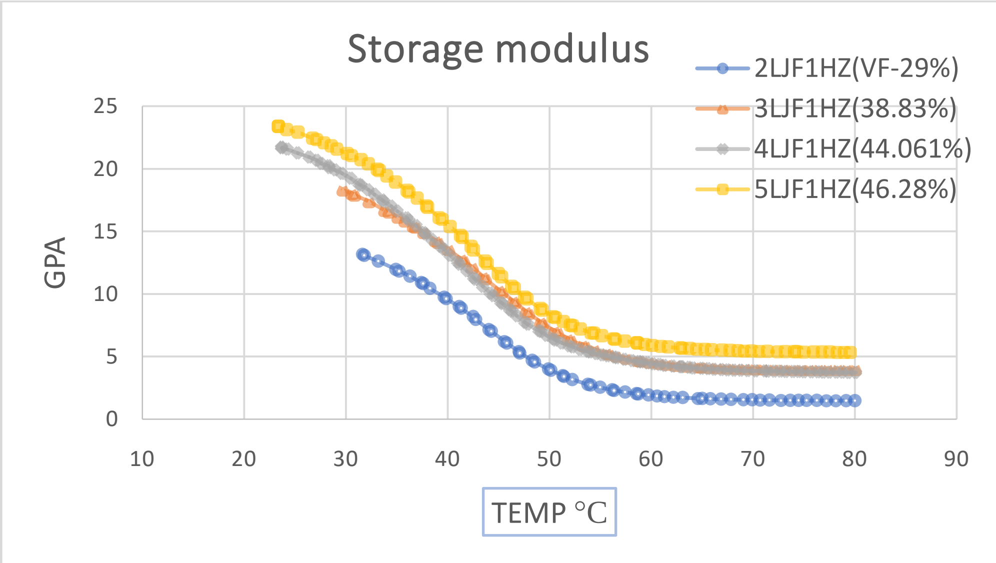

Figure 5. Variations in storage modulus vs. temp. due to change in Jute Fiber content in FRP(Frequency=1Hz)

3.1.2 Effect of temperature on loss modulus of FRP's samples with varying Fiber content (frequency 1 Hz)

Figure 6illustrates the change in the value of loss modulus with respect to increasing temperature for varying percentages of Jute Fiber composite. The Pure epoxy hardener composite has a loss modulus 0.15GPA peak at 49°C, which is attributed to the increased mobility of resin molecular. The Jute Fiber content changes in FRP's result in shifting of the peak to a higher temperature (44.3, 46.425, 46, and 49.1°C) for VF: 29%, VF: 38.83%, VF: 44.061% and VF: 46.28% composite samples. This could be due to the increase in the reinforcement with increase in Fiber percentage in GFRP samples.[11]

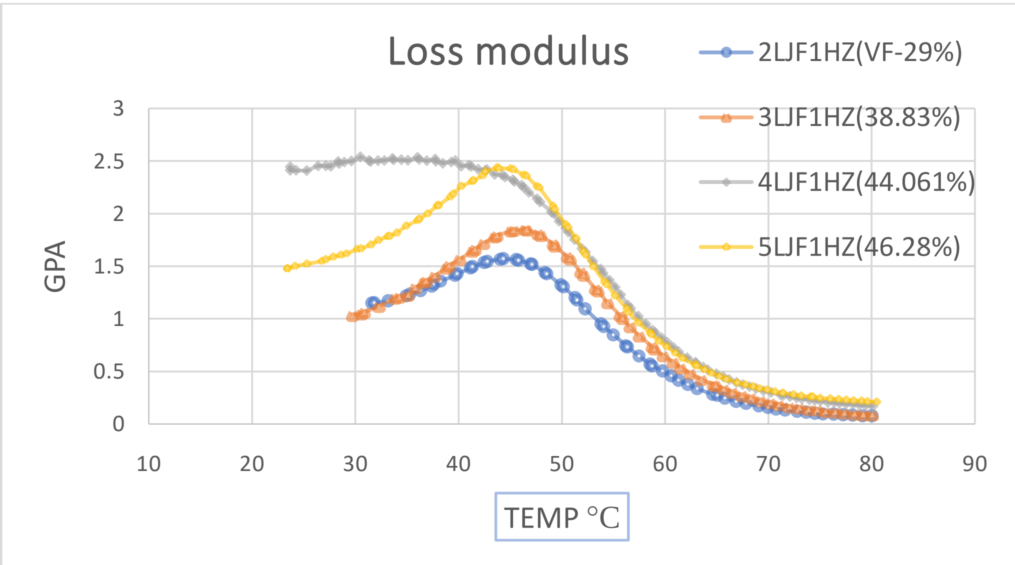

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Figure 6. Variations in Loss modulus vs. temp. due to a change in Jute Fiber content in FRP(Frequency=1Hz).

3.1.3 Effect of temperature on loss factor of FRP's samples with varying Fiber content (Frequency 1Hz):

Changes in the value of the loss factor (tanδ) of the Jute based polymer composites with respect to temperature have beenplotted in Figure 7. Pure Epoxy Hardener composite exhibits a greater tan δ maximum value in contrast to the Fiber-reinforced composite samples. The greater tan δ maximum value for epoxy hardener FRP may be reasoned withextra energy dissipation by internal frictional resistance at the feeble interface matrix material. Among the Fiber reinforced sample, VF 46.28 % reinforced FRP showed the lowest tan δ peak values. As the percentage change in tan δ of VF 46.28 % with respect to Pure epoxy, hardener composite is higher as compared to other FRP's compositions. This seems because of weaker adhesion within the pure epoxy hardener mixture or better energy-dissipating capacity of the pure mixture.[5]

In the case of VF: 46.28% composite, the storage modulus is highest but on the contrary, it also has the lesser value of tan δ as compared to VF 29 %. This is because of the reason that with the increase in the percentage of Jute Fiber content in the FRP composite samples, the strength of the sample increases as a result of which storage modulus increases but on the other side it weakens the bonding between the Jute Fiber and matrix material because of decreasing percentage of matrix material that increases the loss modulus under dynamic loading.[11]

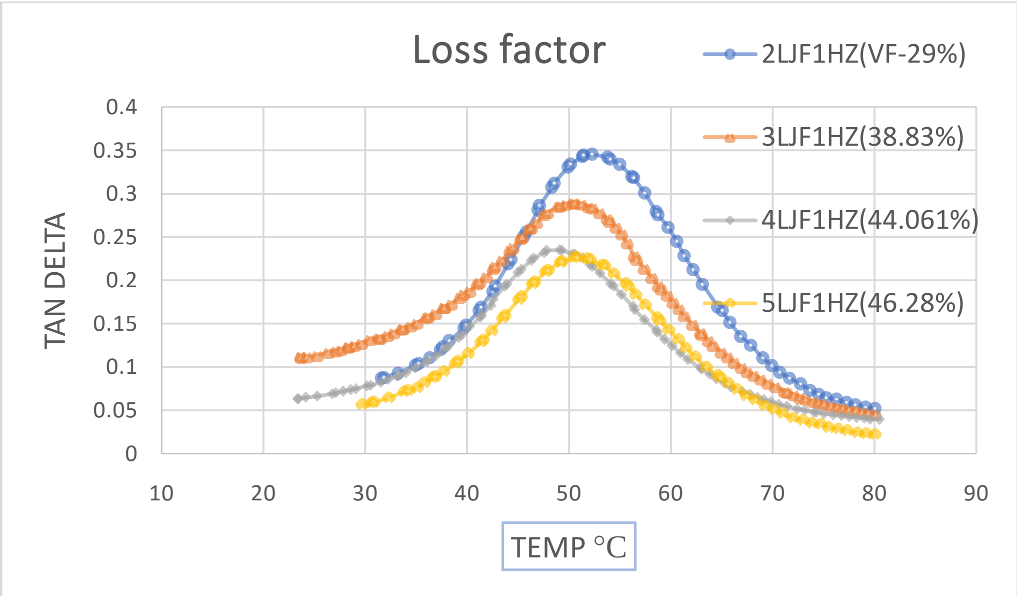

Figure 7. Variations in tan (δ) vs. temp. due to a change in Jute Fiber content in FRP(Frequency=1Hz).

3.2 DMA test results of FRP's samples for the frequency of 2 Hz with varying Fiber content:

The samples of size 50 x 10 x 2 mm were tested under the frequency of 2Hz with a strain rate of 5 microns. Three-point bending mode was selected for analyzing the damping capability of Jute reinforced composites. The results were obtained in the form of plots between storage modulus and frequency, and between tan δ and frequency.

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3.2.1 Effect of frequency (2Hz) on storage modulus of FRP's samples with varying Fiber content:

Fig 8 enunciates the change in E' (storage modulus) with respect to temperature for varying fiber content FRP's sample subjected to a frequency of 2Hz.

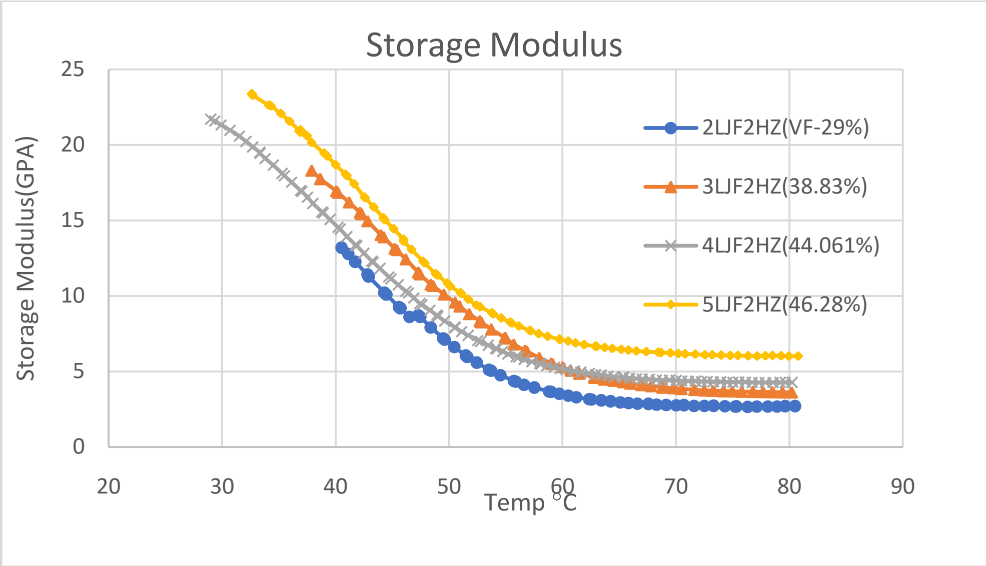

Figure 8. Variation in storage modulus vs temperature due to change in Fiber percentage in FRP's (Frequency=2Hz).

From Figure 8 it is observed by increasing the frequency the value of storage modulus increases from 8.83 GPA to 10.84 GPA at glass transition temperature (49^0 C). This is a very significant increase in value. The storage modulus of all the composite samples dropped drastically between 45°C –50°C which was their glass transition region. The glass transition temperature of the pure matrix has been found to be 41°C, whereas the transition temperature of Jute fiber composites was at 45°C – 50°C.[2]

Table 2. Comparison of storage modulus values of different VF Ratios at 1 Hz and 2 Hz.

Sample	Temperature (^{0}C)	Storage Modulus (GPA) (1Hz)	Storage Modulus (GPA) (2 Hz)	Increased Percentage
Epoxy-Hardener Composite	49	0.29	0.61	110
VF-29 %	49	3.99	7.20	80

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VF-38.83 %	49	7.77	10.10	30
VF-44.061 %	49	8.25	10.73	30
VF-46.28 %	49	8.82	10.83	22

From Table 2 it is observed that storage modulus of pure epoxy hardener sample (2 Hz) are higher than that of Pure Epoxy hardener composites at a frequency of 1 Hz. from table 10 it is seen that at temperature of 49˚C Fiber-reinforced samples have higher storage modulus under a frequency of 2 Hz as compared to the samples tested under 1 Hz.[2]

3.2.2 Effect of frequency (2 Hz) on loss modulus of FRP's samples with varying Fiber content:

Figure 9delineates the changes in loss modulus against increasing temperature for Jute Fiber-reinforced samples. From table 3, it is clear that pure epoxy hardener has greater loss modulus at 49˚C under frequency of 2 Hz as compared to the testing under 1 Hz but it also enlisted that the loss modulus values of FRP's sample tested under the frequency of 2 Hz has more values as compared to the tested under frequency of 1 Hz (figure 9). It may be due to an increase in frequency or increasing the value of cyclic loading at 2 Hz.[5]

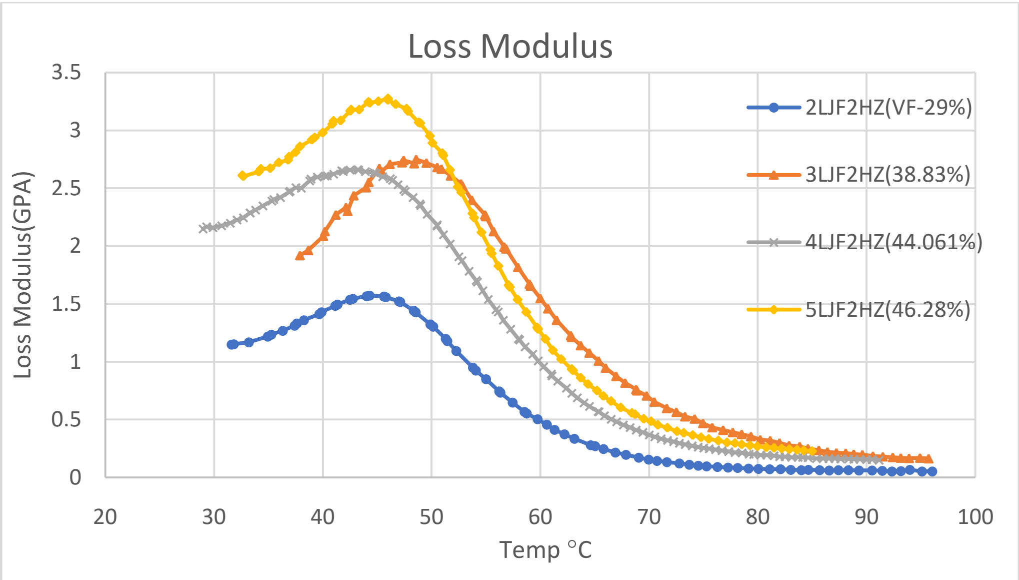

Figure 9. Variation in loss modulus vs temperature due to change in Fiber percentage in FRP's (Frequency=2Hz).

Table 3. Comparison of Loss modulus values of different VF Ratios at 1 Hz and 2 Hz.

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Sample	**Temperature**	**Loss Modulus (GPA) (1Hz)**	**Loss Modulus (GPA) (2 Hz)**	**Increased Percentage (%)**
Epoxy-Hardener Composite	49	0.14	0.23	39
VF-29 %	49	1.32	1.43	8
VF-38.83 %	49	1.71	2.51	24
VF-44.061 %	49	2.00	2.65	25
VF-46.28 %	49	2.07	3.06	32

3.2.3 Effect of frequency (2 Hz) on tan δ of FRP's with varying Fiber content:

Changes in the value of loss factor (tan δ) of GFRP's samples is compared in Fig 10. Pure epoxy hardener composites exhibit a greater tan δ peak value as compared to GFRP composites. The higher tan δ peak value for pure epoxy hardener composite may be attributed to more energy dissipation by internal friction at the weaker interface between Jute Fiber and matrix. [1]

Whereas the Jute Fiber reinforced composites (FRP withVF: 46.28%)showed the lowest tan δ peak values. But there is not much difference between the tan δ for VF: 44% and 46%. Because the tan δ maximum value is linkedwith the bonding of fiber-matrix adhesion, lower tan δ maximum value of VF: 46% corresponds to better adhesion and compatibility between Jute fibers and resin than that of the other FRP's samples.[2]

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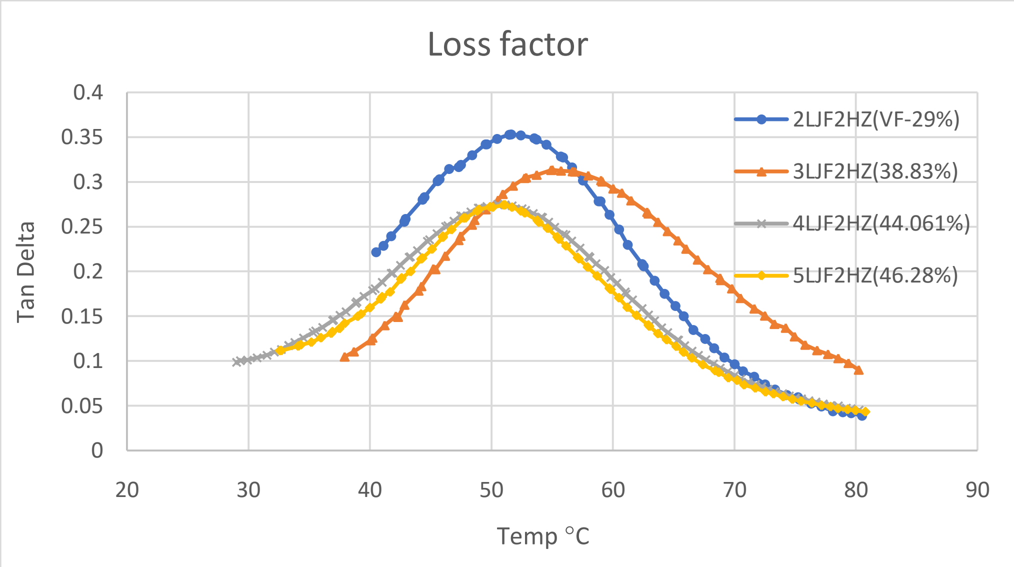

Figure 10. Variation in tan δ vs temperature due to change in Fiber percentage in FRP's (Frequency=2Hz).

Table 4 shows the tan δ corresponding to a frequency of 2 Hz. composite plate having VF: 29% has highest loss factor (0.35) among all FRP'S sample plates.

Table 4. Effect of frequency on tan δ (frequency=2Hz and Tg= 490C)

Samples	**Tan δ Peak Value (at the frequency 2 Hz)**	**% decrease in tan δ**
Epoxy Hardener sample	0.38	---------
VF-29 %	0.35	8
VF-38.83 %	0.31	18
VF-44.061 %	0.27	28
VF-46.28 %	0.27	28

Conclusion

In this study, the Jute fiber-based composite material was tested under dynamic conditions. Different tests were carried out to determine the effectiveness of the variation of Jute Fiber content in reinforced polymer composite. The test results were analyzed and the effects of variation of Jute Fiber on polymer composite were investigated. The following conclusions are obtained from the test results:

1. When VF of Jute fiber changes from zero to 46.28 %, Storage modulus increases from 0.29 GPAto 8.82 GPA at 1Hz frequency during the initial temperature stage.[8]

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2. With the increase in the Jute fiber percentage in the composites, its Storage modulus value is increased by 3041 % for VF of 46.28% at 1 Hz frequency.[11]
3. Similarly, loss modulus increases from 0.15 GPA to 2.07 GPA when VF changes from zero to 46.28%. The value of loss modulus is increased by 1380 % for VF 46.28%.[1]
4. But Loss factor decreases from 0.48 to 0.22 for VF 46.28% at 1Hz Frequency. It has decreased by 54 %.[1]
5. With the increase in frequency from 1 Hz to 2 Hz, the Storage modulus values increases. For VF 46.28%, storage modulus increases from 8.83GPA to 10.84 GPA as frequency increases from 1 Hz to 2 Hz at a temperature of 49^0 C. Its value has increased by 122%.[2]
6. The value of loss modulus increases when the frequency changes from 1 Hz to 2 HZ. Its value increased by 32 % for fiber VF 46.28%.[10]
7. For lower VF the storage modulus increases sharply up to 80% as the frequency increases but with the increasing fiber percentage, this phenomenon decreases.
8. With the increase in the VF Ratio, Glass transition temperature also increases from 41.2 (°C) for pure Epoxy hardener composite to 49.1 (°C) for VF: 46.28%. This is a significant shift in the glass transition temperature.[5]
9. At a frequency of 2 Hz, there is a 28 % decrease in damping factor value as compared to pure Epoxy hardener for VF of 46.28%. This is due to decreased mobility of the fiber because of the increased fiber percentage in the composite.[4]

References

[1] V. Mishra and S. Biswas, “Physical and mechanical properties of bi-directional jute fiber epoxy composites,” *Procedia Eng.*, vol. 51, no. NUiCONE 2012, pp. 561–566, 2013.

[2] K. C. Manikandan Nair, S. Thomas, and G. Groeninckx, “Thermal and dynamic mechanical analysis of polystyrene composites reinforced with short sisal fibres,” *Compos. Sci. Technol.*, vol. 61, no. 16, pp. 2519–2529, 2001.

[3] F. Duc, P. E. Bourban, C. J. G. Plummer, and J. A. E. Månson, “Damping of thermoset and thermoplastic flax fibre composites,” *Compos. Part A Appl. Sci. Manuf.*, vol. 64, pp. 115–123, 2014.

[4] M. S. Meon, M. F. Othman, H. Husain, M. F. Remeli, and M. S. M. Syawal, “Improving tensile properties of kenaf fibers treated with sodium hydroxide,” *Procedia Eng.*, vol. 41, no. Iris, pp. 1587–1592, 2012.

[5] W. K. Goertzen and M. R. Kessler, “Dynamic mechanical analysis of carbon/epoxy composites for structural pipeline repair,” *Compos. Part B Eng.*, vol. 38, no. 1, pp. 1–9, 2007.

[6] M. F. Omar, H. Md Akil, Z. A. Ahmad, A. A. M. Mazuki, and T. Yokoyama, “Dynamic properties of pultruded natural fibre reinforced composites using Split Hopkinson Pressure Bar technique,” *Mater. Des.*, vol. 31, no. 9, pp. 4209–4218, 2010.

[7] A. Etaati, S. Pather, Z. Fang, and H. Wang, “The study of fibre/matrix bond strength in short hemp polypropylene composites from dynamic mechanical analysis,” *Compos. Part B Eng.*, vol. 62, pp. 19–28,

ISSN:0971-1260
Vol-22-Issue-16-August-2019

2014.

[8] M. Jawaid, H. P. S. Abdul Khalil, and O. S. Alattas, “Woven hybrid biocomposites: Dynamic mechanical and thermal properties,” *Compos. Part A Appl. Sci. Manuf.*, vol. 43, no. 2, pp. 288–293, 2012.

[9] F. M. Salleh, A. Hassan, R. Yahya, and A. D. Azzahari, “Effects of extrusion temperature on the rheological, dynamic mechanical and tensile properties of kenaf fiber/HDPE composites,” *Compos. Part B Eng.*, vol. 58, pp. 259–266, 2014.

[10] K. E. Reed, “Dynamic mechanical analysis of fiber reinforced composites,” *Polym. Compos.*, vol. 1, no. 1, pp. 44–49, 1980.

[11] M. Idicula, S. K. Malhotra, K. Joseph, and S. Thomas, “Dynamic mechanical analysis of randomly oriented intimately mixed short banana/sisal hybrid fibre reinforced polyester composites,” *Compos. Sci. Technol.*, vol. 65, no. 7–8, pp. 1077–1087, 2005.