

A Study on Composites Reinforced with Nano-Fibres of the Jute Plant

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Abstract

The dispersion of jute nanofibres inside an epoxy polymer matrix has been used to investigate polymer-based nanocomposites. Thermal properties of a composite are critical in assessing product performance and forecasting processability features of polymers in certain applications. The thermal behaviour of the interface between nanofiber reinforcement was investigated using thermogravimetric analysis and differential scanning calorimetry. The inclusion of nanofibres with varying weight percentages (1wt. percent to 5wt. percent) has been examined and compared to base composites. The addition of jute nanofibres considerably improves the thermal stability of nanocomposite. The nanofibre reinforcement between the matrix resin molecules provided some thermal degradation resistance. DMA measurements are performed with a single frequency and constant deformation amplitude while the temperature is varied. Measurements that vary the amplitude of deformation or use several frequencies give additional information. The dynamic characteristics are represented in terms of storage modulus, loss modulus, and damping factors, all of which are temperature, time, and frequency dependent. The dispersion of nanosized fibres inside polymer matrices has a substantial impact on their physical characteristics. The interface macromolecular chains-nanofibre interface and the large area of the nanofibres are the primary sources of alteration.

Keywords: *Nano-Fibres, Jute Plant, Polymer, Epoxy polymer, Nanocomposites*

INTRODUCTION

The physical properties of the interface become dominant over the bulk properties of the polymer matrices in nanocomposites. The addition of nanosized fibres to a polymer matrix often improves the polymer's thermal and thermo-oxidative degradation, the young modulus, and the strength of the polymer matrix, as well as influencing the crystallisation process. In most situations, the effect of nanofibres is a relatively little increase in the temperature at which the polymer's mass loss is greatest.

This characteristic, which is easily acquired using thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC), may be thought of as a fingerprint of the creation of a polymer nanofibre interface. The interaction of a nanofibre with polymer molecules in the presence of heat energy from working conditions may worsen the deterioration of polymer composites. A substantial amount of research has been conducted on the heat breakdown of polymers in nanocomposites. For extremes, a dynamic mechanical that analyses the characteristics of materials as they are

deformed under periodic stress resin (DGEBA) and a Triethylene Tetramine hardner (HY956) were utilised.

The studies into Bisphenol-A epoxy. M/s Ecmas Pvt Limited, Visakhapatnam, offered the glass fibre woven plain textiles with a phase difference. Glass fibre has a 90° average fibre area weight (FAW). However, most real-world materials, including polymers, are viscoelastic and have a density of 410g/m². Nanomaterials can be used to modify both the structural and functional aspects of coatings.

The phase difference between the stress and strain sine waves is 0° if the material is entirely elastic (i.e., they are in phase). The phase difference is zero if the substance is entirely viscous. The purpose of this research is to investigate the heat degradation behaviour of nanofibre reinforcement in an epoxy polymer matrix. DMA employs varied sinusoidal stress and measures the resulting sinusoidal strain. If the material is being analysed, a thermal analysis approach is used to compare the thermal deterioration of varied weight % reinforcement with base composite analysis.

EXPERIMENTAL WORK

Materials

Mechanical milling and chemical treatment were used to obtain nanofibres from natural fibre Jute. Scanning electron microscopy (SEM) and X-ray diffraction were used to examine the structural shape and size. The underlying polymer substance for the current research is epoxy, one of the most extensively utilised polymers.

Characterization of Nano fibres

An X-Ray diffractometer (Phillips X Pert Pro Diffractometer model) was used to study jute nanofibres at a scanning rate of 4°/min with Cu, K radiation at 45 kv and 40mA. The size of the jute fibres was determined using Scherrer formulae. A JEOL type SEM was used to acquire images of jute fibres and microfibrils. The produced jute fibres are micro to nano in size after various milling hours.

Preparation of Jute nanofibre composites

Jute nanofibres with varied percentage weight (1wt% to 5wt%) reinforced in epoxy resins to make nanofibre composites by hand lay-up process. The composites were made using a 50 wt. percent / 50 wt. percent proportion of glass fibre woven mat and epoxy resin. The epoxy resin was

combined with a mechanical stirrer at 750 rpm for 30 minutes at room temperature and reinforced with varied weight percentages of Jute nanofibre reinforcing (0, 1, 2, 3, 4, and 5 wt. percent).

The curing agent TETA was then added to the mixture by weight for each 100 gm of epoxy resin and well stirred until it became homogenous. Finally, the composite is allowed to cure for 24 hours at room temperature. The final laminate was used to make samples for testing the thermal characteristics according to ASTM standards.

Thermal analysis of nanofibre composites

TGA is a technique extensively used in research and testing to investigate the properties of polymer nanofibre composites. This analysis is used to investigate the degradation temperatures, absorbed moisture content of materials, inorganic and organic component levels in materials, and the breakdown sites of explosives and solvent residues. It is also frequently used to calculate corrosion kinetics in high temperature oxidation. The specimens were heated from room temperature to 600°C at a rate of 10°C per minute. To compare the effect of different weight percentages (1-5 wt. percent) of

jute nanofibre composites, they were oven aged for 10 minutes in hot air at various temperatures.

Pyris Diamond DSC type Perkin Elmer apparatus was used to perform differential scanning calorimetry (DSC) of base composite and nanofibre reinforced with varied weights. The current study used 5-10 mg of materials at a scanning rate of 20°C/min and temperatures ranging from 30-300°C in a nitrogen environment. Following that, the samples were kept at 300°C for 5 minutes before being cooled at a rate of 20°C/min from 300° to 30°. The melting temperature, heat of fusion, and crystallisation temperature were all measured. Jute nanofibre composites of various weight percentages (base composite and with 1 to 5 wt. percent JNF/epoxy composite) were manufactured as rectangular bars of dimension 40x10x3 mm³ in DMA according to ASTM specifications. As indicated in Fig.1, the specimens are subjected to the three point bending test technique.

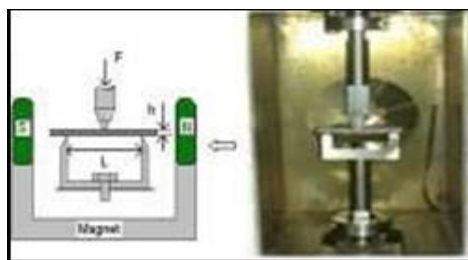


Fig.1. Three point Bending Test set up

RESULTS AND DISCUSSION

Differential scanning calorimetry

DSC measures the heat impacts of phase transitions and chemical processes as a function of temperature. Crystallization is an exothermic process, whereas melting is an endothermic reaction. Thermal information such as the glass transition temperature, crystallisation temperature, and melt temperature may be obtained using DSC curves. To determine the thermal transitions, the DSC curves of base composite and 1 wt. percent to 5 wt. percent jute nanofibre reinforced composites were examined in the temperature range of 30° C to 300° C, as shown in the figure. 2. Although the glass transition temperature of the nanocomposites did not change considerably as a result of the addition of nano jute fibres, the inclusion of jute nanofibres did impact the crystallisation behaviour of the polymer composite.

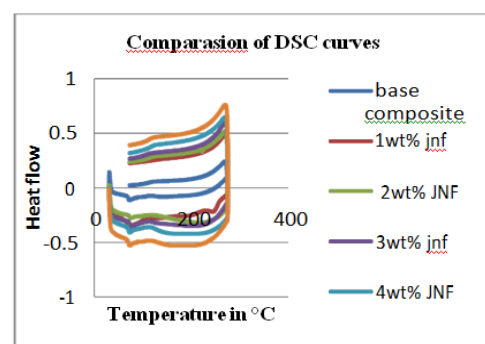


Fig.2. Comparision DSC curves of base composite and nanofibre reinforced composites

The crystallisation process commenced at a higher temperature of 71°C for pure epoxy composites and 72°C to 75°C for all jute nanofibre reinforced composites. When compared to pure epoxy composites, the inclusion of nano jute fibres raised the crystallisation temperature T_c by up to 1°C- 4°C. This finding suggests that the nucleating impact of jute nanofibre composites has been enhanced. Jute nanofibres acted as a nucleating agent, facilitating crystallisation. This is due to a greater contact between the surface of the nano jute fibre and the chains. The crystallinity increase might potentially be explained by the nucleating impact of jute nanofibre. Among these are the filler's nanoscale dispersion and orientation in the matrix. When compared to pure epoxy composites, all hybrid composites showed a greater melting temperature.

Thermogravimetric analysis

TGA curves were used to examine the heat degradation behaviour of pure epoxy composites and Jute nano fibre reinforced polymer composites with 1-5wt percent Jute nanofibre loading. A quick decline in sample mass suggests thermal deterioration of the materials; however, including jute nanofibre into the matrix improved the degradation temperature

commencement of the composites as well as the breakdown temperature.

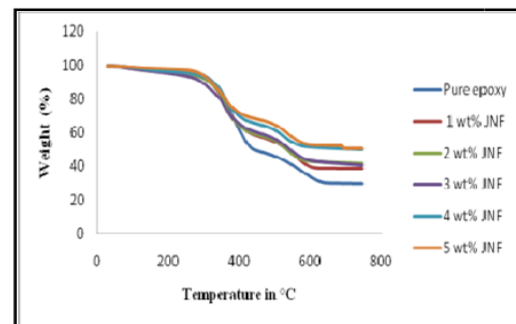


Fig.3. Comparison TGA curves of base composite and nanofibre reinforced composites

According to Fig.3, the thermal deterioration of the base composite began at 344.2°C and reached 100% degradation at 560°C. However, the addition of jute nanofibres significantly improved the thermal durability of the nanocomposites, with an initial degradation temperature of 370°C and a final breakdown temperature of 583°C. This suggests that increasing the jute nanofibre content of a fibre reinforced composite has a crucial role in limiting its rate of heat deterioration. The primary source of thermal stability increase might be a highly crosslinked multilayer epoxy matrix, which provides extra intermolecular bonding between fibre and matrix, allowing more thermal energy to be spread over these bonds inside the interface.

Dynamic Mechanical analysis

Jute nanofibre reinforcement with pure epoxy Polymer composite DMA results Dynamic mechanical analysis was used to investigate the effect of a percentage weight of 1 to 5% nanofibre reinforcement. Dynamic mechanical analysis was performed on the base composite and nanofibre composite samples to better understand the nanofibre interaction in the composite as the percentage weight (1-5wt. percent) of nanofibre increased. DMA studies demonstrate that variations in a composite material's storage modulus, loss modulus, and tan delta as temperature increases can disclose a lot about its thermal transition.

Storage Modulus

The three point bending technique was used to test Jute nanofibre composites with varied weight percentages, and the storage modulus comparison graphs are given in Fig.4.

When compared to pure epoxy composites, nanocomposites have a slightly greater storage modulus with the inclusion of nanofibres. All of the composite samples' storage moduli declined dramatically between 65–80 °C, which was their glass transition temperature. The glass transition temperature of pure composite was determined to be 65 °C, whereas that of Jute nanofibre composites was 70 – 75 °C.

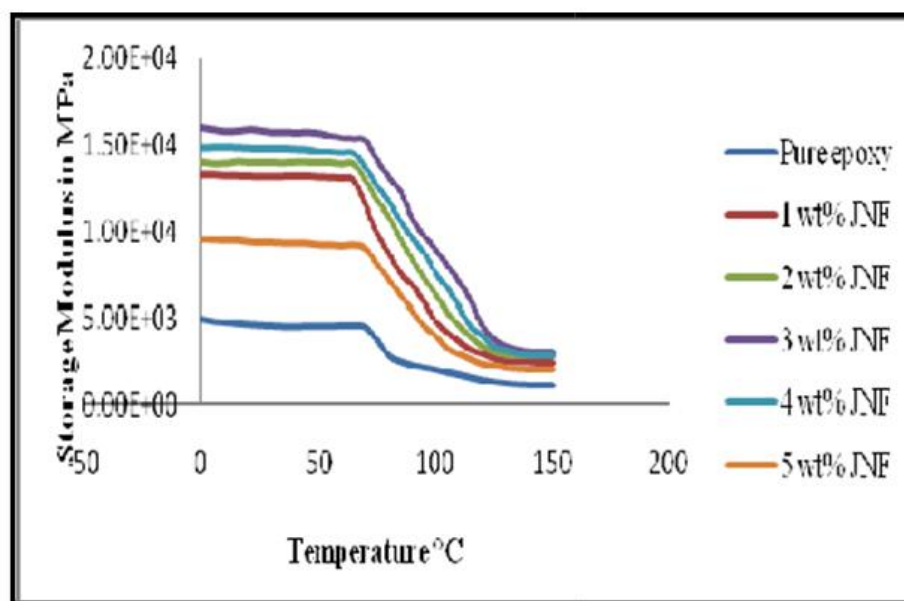


Fig.4 Comparison of Storage Modulus vs Temperature of base/ Jute nanofibre Composites

The storage modulus of a Jute nanofibre reinforced composite increases as the fibre

concentration increases in both the glassy and rubbery regions. This discovery is

most likely connected to the interaction of the epoxy hydroxyl group with hydroxyl groups known to occur on damaged locations on the Jute nanofibre surface or as a result of atomic scale defects generated along Jute nanofibre composites. The rise in glass transition temperature also implies an increase in the degree of contact between the polymer chains and the surface of the Jute nanofibre. The inclusion of the Jute nanofibre enhances the storage modulus, which might be attributed to the combination action of the nanofibres embedded in a viscoelastic matrix and mechanical constraints. At high concentrations, the fibre lowers matrix mobility and deformation, allowing stress to be transmitted from the epoxy matrix to the Jute nanofibre reinforcement.

Loss Modulus

The value of the loss modulus, which measures the degree of viscous dissipation in the composites, exhibited some unexpected behaviour. The loss modulus (E'') varies with temperature for both pure epoxy and composites containing 1 to 5 wt.% jute nanofibre.

Figure 5 compares the loss modulus versus temperature graphs of the base/nanofibre composite samples. The T_g of Jute nanofibre composites is somewhat greater, with a wider range of the transition area than the pure epoxy composite sample.

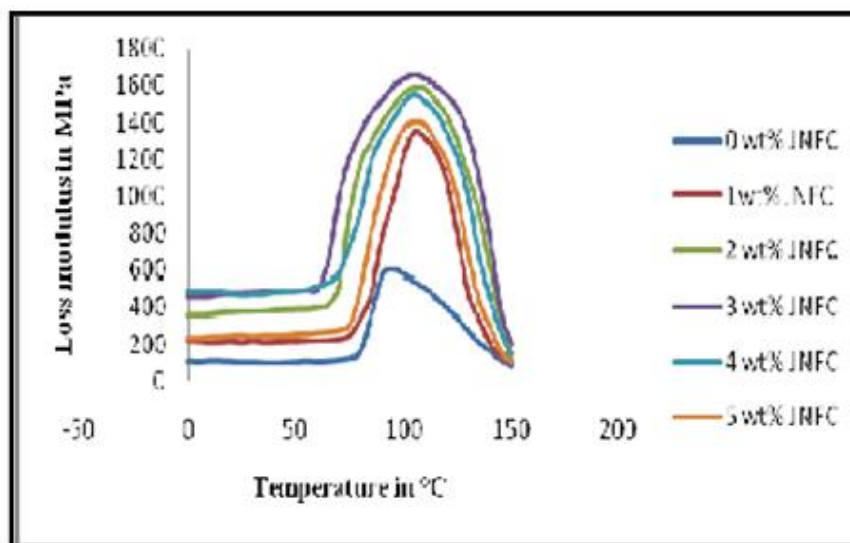


Fig.5 Comparsion of Loss modulus curves of base/ Jute nanofibre composites

Because the loss factors are sensitive to molecular movements, it is possible that the mobility of the polymer molecular chains reduces when the chains are hampered by the nanofibre reinforcement, resulting in a change in T_g . A good attachment of Jute nanofibre with the surrounding polymer matrix will also enhance the dynamic modulus by inhibiting molecular mobility to some extent. The loss modulus increases as the fraction of Jute nanofiber increases. This might be attributed to energy losses induced by molecule and Jute nanofibre rearrangements, as well as internal friction between the Jute nanofibre and the epoxy polymer matrix.

Tan Delta

The peak of the $\tan \delta$ curve is a common T_g measuring point, and it is generally easier to separate than the commencement

of the reduction in the storage modulus. The $\tan \delta$ vs temperature curve can reveal considerably more about a system than just its T_g . The breadth of the $\tan \delta$ peak can be used to determine how homogenous a system is. A system contains extremely broad peaks that are often made of varied polymer chain lengths or topologies, resulting in a temperature range that initiates large viscous chain movements for the individual components. Systems with narrow peaks, on the other hand, have a more restricted distribution of chain types and molecular weights. The amplitude or height of the $\tan \delta$ curve is proportional to a material's capacity to dissipate energy via segmental motion. Systems with tall $\tan \delta$ peaks have larger ratios of energy absorbing viscous movements and are thus often tougher than systems with low $\tan \delta$ amplitudes.

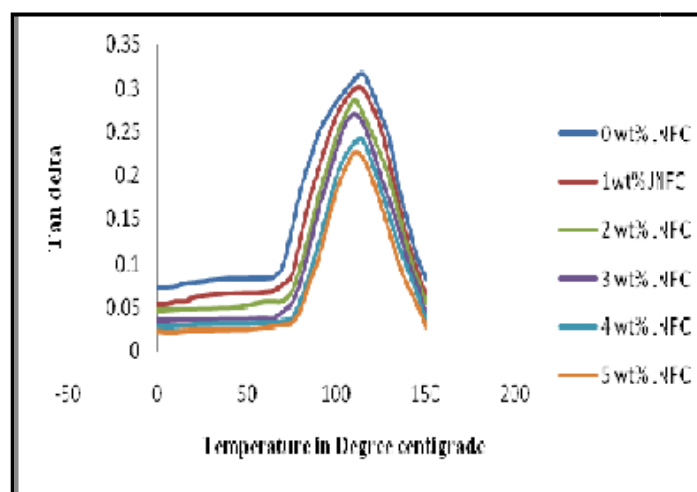


Fig.6 Comparison curves of Tan delta for base/ Jute nanofibre composites

According to Fig.6, the intensity of the tan peak decreases as the amount of Jute nanofibre reinforcement increases as compared to the pure epoxy composite. The maximum damping parameter of 0.220 of 5 wt percent JNF composite was observed, with a 36 percent improvement when compared to pure epoxy composite. This could be due to a decrease in the mobility of polymer molecular chains as a result of reinforcement, which resulted in a decrease in the height and sharpness of the peak in the curves. The physical interaction between the polymer and reinforcements, which restricts the segmental mobility of the polymer chain in the vicinity of the nanofibre reinforcement, can be attributed to the increase in modulus and positive shift in tan peak position. The degradation of the polymer chain structure is responsible for the decrease in elastic properties and increase in damping at higher temperatures.

CONCLUSIONS

TGA, DSC, and DMA were used to evaluate the thermal characteristics of epoxy polymer filled with Jute nanofibre composites under nitrogen. The experimental data is compared to the base/nanofibre composites. Depending on the temperature area, the nanofibre composites exhibit some stabilisation

destabilisation interaction. The addition of nanofibre reinforcement raises the crystallisation temperature and lowers the thermal degradation temperature. In the first weight loss stage, jute nanofibre stabilises the polymer molecules and delays the emergence of significant cracks. The amount of nanofibre composites used had a stronger stabilising or destabilisation impact. However, smaller particle size nanofibre composites have a bigger influence on the thermal characteristics of nanofibre composites. The dynamic characteristics of polymer epoxy resins vary with temperature. The storage modulus reduces as temperature rises, whereas the loss modulus rises (the fact which should facilitate internal damping). According to the DMA results, the higher modulus, together with the positive shift in tan delta peak location, is due to the physical contact between the polymer and nanofibres, which limits the segmental mobility of the polymer chains near the Jute nanofibres.

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