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Thermal Properties of Jute Nanofibre Reinforced Composites

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Abstract: Polymer based nanocomposites have been subject of investigation by the dispersion of jute nanofibres within epoxy polymer matrix. Thermal properties of a composite play a vital role in evaluating the product performance as well as predicting the processibility characteristics in polymers in specific applications. The thermal behaviour of the interface between nanofibres reinforcement have been studied by thermogravemetric analysis and Differential scanning calorimetry. The addition of nanofibres with different weight percentages has been (1wt.% to 5wt.%) studied and compared with base composites. The thermal stability of nanocomposite is significantly improved due to incorporation of jute nanofibres. These nanofibre reinforcement between the matrix resin molecules offered some resistance towards the thermal degradation.

Keywords : nanofibres, calorimetry, nanocomposites, polymer

1. Introduction

The dispersion of nanosized fibres with in polymer matrices can affect significantly their physical properties. The main source of modification is due to the interface macromolecular chains-nanofibre and to the huge area of the nanofibres[1-8]. In nanocomposites the physical properties of the interface become dominant over the bulk properties ofthe polymer matrices.

The addition of nanosized fibres to polymer matrix typically enhances the thermal and thermo-oxidative degradation of the polymer, the young modulus, and the strength of the polymer matrix and affects the crystallization process. In most cases, the effect of nanofibres consists in a rather modest increase of the temperature at which the mass loss of the polymer is highest. This parameter easily obtained by thermogravemetric analysis (TGA) and Differential scanning calorimetry (DSC) analysis can be considered a fingerprint of the formation of a polymer nanofibre interface.

The degradation of polymer composites may be aggravated due to the interaction of a nanofibre with polymer molecules in the presence of thermal energy from working environments. These have been a considerable amount of work on the thermal degradation of polymers in nanocomposites[.A series of experiments on the thermal oxidation of filler-free metallocene cyclic olefin copolymer and titanium oxide composites. The thermal degradation behaviour of LDPE ,PEA and EEA copolymer with calcium carbonate was discussed[9-15].

The nanocomposite system coatings can be obtained by the traditional coatings technology. i.e., by filling with nanometric scale materials. Both structural and functional properties of coatings can be modified by filling with nano materials. The aim of the work is to study the thermal degradation behaviour of nanofibre reinforcement in epoxy polymer matrix. and to compare the thermal degradation of different weight percentage reinforcement with base composite.

2. Experimental Work

2.1 Materials

Nanofibres were extracted from natural fibre Jute by mechanical milling and chemical treatment. The structural morphology and size was analysed by Scanning electron microscope(SEM) and X-ray diffraction .

Epoxy, one of the most commonly used materials is the base polymer material for the current research work. Bisphenol-A epoxy resin (DGEBA) along with a Triethylene Tetramine hardner (HY956) was used for the investigations. Glass fibre woven plain fabrics were supplied by M/s Ecmas Pvt Limited, Visakhapatnam. The average fibre area weight (FAW) of glass fibre was 410 g/m^2.

2.2 Characterization of Nano fibres

X-Ray diffractometer (Phillips made X Pert Pro Diffractometer model) analyzed the nanofibres of jute at a scanning rate 4°/min with Cu, K_α radiation at 45 kv and 40mA. The size of the jute fibres were determined by using Scherrer formulae. The Scanning Electronic microscope (SEM) images of jute fibres and microfibrils were taken with JEOL model Scanning Electronic microscope. It is observed that the obtained jute fibres are micro to nano scale at different milling hours.

2.3 Preparation of Jute nanofibre composites

The Jute nanofibres with varying percentage weight (1wt.% to 5wt.%) reinforced in epoxy resins to prepare nanofibre composites by hand lay-up technique. The composites were prepared by using glass fibre woven mat and epoxy resin with 50 wt.% / 50 wt.% fraction. The epoxy resin is reinforced with different weight percentage of Jute nanofibre reinforcing (0, 1, 2, 3, 4 and 5 wt. %) were mixed by using a mechanical stirrer at 750 rpm for 30 minutes at room temperature. Then, for each 100 gm of epoxy resin, 12% of curing agent TETA was added to the mixture by weight and thoroughly mixed until it became uniform. Finally, the composite is allowed to fully cure at room temperature for 24 hours. The finished laminate was used to prepare samples for investigating the thermal properties as per ASTM standards.

2.3.1 Thermal analysis of nanofibre composites.

The thermogravemetric analysis (TGA) is commonly employed in research and testing to determine characteristics of polymer nanofibre composites. This analysis is used to study the degradation temperatures, absorbed moisture content of materials, the level of inorganic and organic components in materials, decomposition points of explosives and solvent residues. It is also often used to estimate the corrosion kinetics in high temperature oxidation.The specimens was heated from room temperature to 600ºc at heating rate of 10 ºc /min. For comparing the effect of different weight percentages (1-5

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wt.%)of jute nanofibre composites were also oven aged in hot air at various temperatures for 10 min.

Fig.1.Thermogravimetric Analyzer

Differential scanning calorimetry (DSC) of base composite and nanofibre reinforced with different weights were carried out by using Pyris Diamond DSC model Perkin Elmer apparatus. The present investigation 5-10 mg of samples at scanning rate of 20ºC/min and temperature of 30-300ºC under nitrogen atmosphere. Subsequently, the samples were held at 300°C for 5 minutess and then cooled from 300º to 30ºC at the rate of 20°C/min. Corresponding melting temperature; heat of fusion and crystallization temperature were recorded.

Fig.2. Differential Scanning Calorimetry

3. Results and Discussion

Thermal degradation of Nanofibre composites

Thermogravimetric curves provide information regarding polymerization reactions, the efficiencies of stabilizers and activators, the thermal stability of final materials and direct analysis.TGA measures the amount and rate of change in the mass of a sample as a function of temperature of time in a controlled atmosphere. The measurements are used primarily to determine the thermal and oxidative stabilities of materials as well as their compositional properties.

Thermogravimetric analysis (TGA)

The thermal degradation behaviour of pure epoxy composite and Jute nano fibre reinforced polymer composites with 1wt.% to 5wt% Jute nanofibre loading has been employing by TGA curves as shown in figure. A sudden drop in the mass of the sample indicates the thermal degradation of the materials, however adding the nano jute fibre in the matrix increased the degradation temperature onset of the composites and also increased the decomposition temperature.The major source of thermal stability improvement may be due to the fact that a highly cross linked multilayer epoxy matrix which produces additional intermolecular bonding between fibre and matrix, allowing more thermal energy distributed over these bonds within interface.

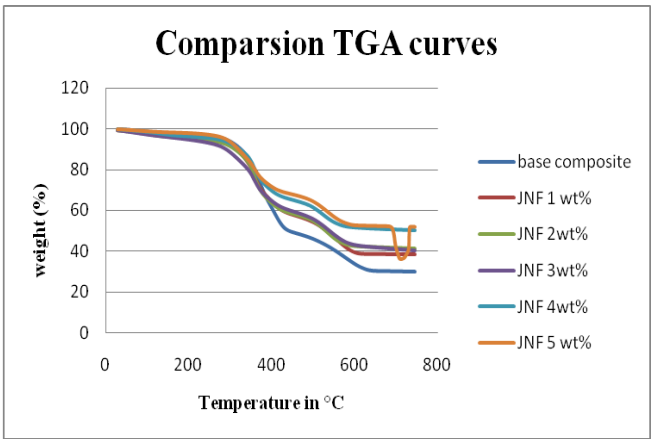

Fig.3. Comparision TGA curves of base composite and nanofibre reinforced composites

It is evident from the figure that the thermal degradation of base composite (pure epoxy) started at 344.2°c and 100 % degradation was noticed at 560°c. However with the incorporation of jute nanofibres, there was substantial enhancement in the thermal stability of the nanocomposites with an initial degradation temperature at 370°c and final decomposition at 583°c. The rate of degradation was found to be slightly lower in case of 5wt.% composites as shown in the Fig.3. This indicates that a significant increase in the jute nanofibre content of fibre reinforced composite play an important role in controlling its rate of thermal degradation. The nano jute reinforcement in between the matrix resin molecules offered some resistance towards their thermal degradation showed a lowering trend with the increase in nano fibre content The major source of thermal stability improvement may be due to the fact that a highly cross linked multilayer epoxy matrix which produces additional intermolecular bonding between fibre and matrix allowing more thermal energy distributed over these bonds within the interface [3, 4, and 5]

Differential scanning calorimetry (DSC) is a thermo analytical technique in which the difference in the amount of heat required to increase the temperature of a sample and reference are measured as a function of temperature. Both the sample and reference are maintained at very nearly the same temperature throughout the experiment. DSC monitors heat effects associated with phase transitions and chemical reactions as a function of temperature. Crystallization is a typical exothermic process and melting a typical endothermic process. The mechanical behavior of polymers changes markedly at the glass transition temperature it is an important characteristic of every polymer composite. The thermal degradation began to occur only after the materials have absorbed certain amounts of the heat energy. The heat initiated the degradation processes and the breaking down of the fibres and matrix structures by causing molecular chain ruptures.DSC curves are used to obtain thermal information such as the glass transition temperature, crystallization temperature and melt temperature.

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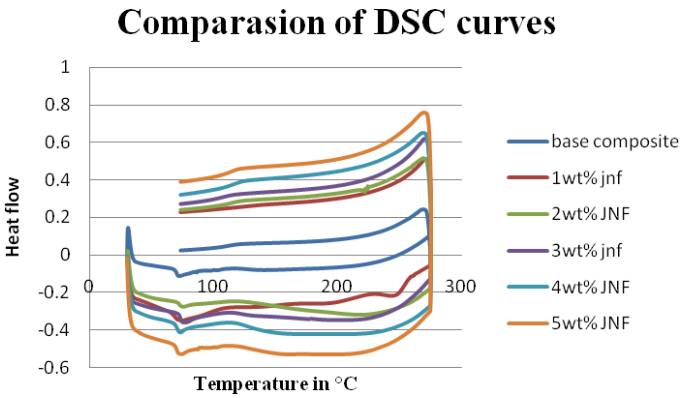

Fig.4. Comparision DSC curves of base composite and nanofibre reinforced composites

The DSC curves of base composite and 1 wt.% to 5 w.% jute nanofibre reinforced composites were compared in the temperature range of 30° c to 300°c to determine the thermal transitions as shown in the figure4. It can be seen that the glass transition temperature of the nanocomposites did not change significantly due to the addition of nano fibres, however the addition of nanofibres did affect the crystallization behavior of the polymer composite. The crystallization began at a higher temperature 71°c for pure epoxy composite where as for all nano fibre reinforced composites 72°c to 75°c. The addition of nano fibres increased the crystallization temperature T_c by up to 1°c- 4°c compared to the pure epoxy composites. This result indicates that the nucleating effect of nano jute fibres composites was strengthened. The nano fibres played the role of nucleating agent and facilitated crystallization. This is due to stronger interaction between nano jute fibre surface and chains. The nucleating effect of nano fibre could also explain the increase of crystalline. The nano scale dispersion of the filler and its orientation in the matrix are among these factors. All hybrid composites had a higher melting temperature compared to pure epoxy composites.

4. Conclusions

The thermal properties of epoxy polymer filled with Jute nanofibre composites under nitrogen were investigated by TGA and DSC and compared with base composites. from the results obtained, nanofibres show some stabilization/destabilization interaction according to the temperature region. The nanofibre reinforcement improves the crystallization temperature and thermal degradation temperature .Jute nanofibre stabilizes the polymer molecules and delays the occurrence of major cracking in the primary weight loss stage. A greater stabilization or destabilization effect was observed increasing with the amount of nanofibre composites. However nanofibre composites of smaller particle size have greater effect on the thermal properties of nanofibre composites.

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