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Effect of Carbon Nanotube on Mechanical Properties of Jute Fibre Reinforced Polyester Composite

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Abstract

The current study studies how carbon nanotubes affect the mechanical characteristics of polyester composites reinforced with jute fiber, both treated and unprocessed. Alkali was used to cure jute textiles. Composites with treated and untreated jute fibre with 5%, 10% and 15% jute fibre loading with and without carbon nanotube were prepared using hand lay-up process. Carbon nanotubes varied from 0.2%, 0.4% and 0.6%. Tensile, flexural, and strength of impact all rise at higher fiber loading, whether or not nanotubes are being utilized. The 0.6% carbon nanotube reinforced alloy exhibits the highest rate of growth. Addition of carbon nanotube resulted in the enhancement in the mechanical properties due to strong interfacial bonding as indicated in SEM images.

Keywords: Carbon nanotubes; nano fibers; composite; jute fibre; polyester

INTRODUCTION

Low cost and improve sustainability are the major factors for growing interest in developing natural fiber polymer composites [1] and finding applications in various fields such as textiles, building and constructions, automobile etc. [2]. Improvement in abrasive wear behaviour of the natural fiber composite is leading towards its suitability for tribological applications [3, 4]. Applications of natural fiber polymer composites have resulted in reduced weight resulting in reduced energy consumption [5]. Because of their inherent advantages some of the leading automobile manufacturers are using natural fiber polymer composites for various automobile parts [6, 7]. Poor interfacial bonding and hydrophilic property of natural fiber composites are affecting their performance [8, 9]. Various chemical treatment has been carried out to overcome these problems [5, 10–15]. To overcome, limitations of natural fiber polymer composites, hybrid composites are gaining attention and have potential to overcome these limitations of natural fiber polymer composites [6, 16–22]. Hybrid composites exploits the synergy between natural fiber and nanofillers to enhance their performance [23]. Increase in the mechanical properties of hybrid composites were reported with the addition of carbon nanotubes in natural fibre reinforced polymer composites [20, 21, 24–26]. Improvement in impact properties and reduction in water absorption have been reported with the addition of nanofillers in natural fibre polymer composites [22, 27]. Due to the excellent ability of nanofillers in enhancing the properties of polymer composites, nanofillers are gaining attention in the field of polymer composite research for different applications [28–34]. Because of its remarkable properties, addition of carbon nanotubes in

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polymer matrix enhances its mechanical, electrical, and thermal properties [35, 36]. However, interface between carbon nanotubes and polymer matrix plays an important role in the reinforcement of polymer composites [37–39]. Carbon nanotubes are the most ideal and promising reinforcements for various applications [40–42]. Increase in the mechanical properties have been reported with the addition of carbon nanotubes in polypropylene carbon nanotubes composites [43, 44] and polyester carbon nanotubes composites [45].

MATERIALS AND METHODS

Materials

Unsaturated Polyester (matrix) was obtained from Uvas Solutions Private Ltd. Jute fibre is used as reinforcing fibre and obtained from Go green products. Cobalt octate, used as activator was obtained from Arihanta Metallica. Veekay Chemicals gave the catalyst, methyl ethyl ketone peroxide, the or MEKP. Multiwalled carbon nanotube was obtained from Adnano Technologies.

Alkaline Treatment of Fibre

Jute fibers were chopped in a length of 4-6 mm.5% NaOH solution was prepared using distilled water. Chopped fibers were treated in 5% NaOH solution for 24 hours at room temperature. The fibers were cleaned repeatedly in distilled water after a period of one day. The fibers were dried completely before being used for preparing composites.

Preparation of CNT/Polyester Mixture

CNT/polyester mixture is prepared with 0.2%, 0.4% and 0.6% of CNT composition (by weight) 0.2 weight % of CNT was dispersed in acetone in two steps. Initially mechanical agitation was carried out for half an hour and then the mixture was sonicated was another half an hour at an ambient room temperature. Following a one-hour vigorous stirring period, the polyester resin was added to the CNT/acetone mixture and sonicated for an additional hour. After that, the mixture was heated to hundred degrees Celsius for ten hours in order to evaporate the acetone from the mixture.

The CNT/polyester mixture was then cooled at room temperature and activator and catalyst was added. This matrix solution was then used to prepare the composite. The same procedure was repeated to prepare CNT/polyester mixture having 0.4% and 0.6% CNT.

PROCESSING (EXPERIMENTAL)

Hand-lay-up technique is used for preparing composites. To prevent the polymer from bonding to the mold surface, a release gel is sprayed on it. Roughly minced jute fibers. 4-6 mm length is placed on to the mold surface and the mixed resin is poured onto the surface of the mold. A brush and scraper are used for uniformly distributing the polymer.

Different percentages of fibre and CNT is taken to manufacture the composite. To get rid of any trapped air and superfluous polymer, a roller is pushed over the fiber-polymer layer while delivering little pressure. Every time fiber and polymer are loaded, the procedure is repeated. The derived composite part is removed from the mold and handled further after it has been cured for 30 minutes at room temperature. The composites in the following batches had been created.

- Untreated chopped fibers with different loadings 5%, 10% and 15% is placed on the mold surface and unsaturated polyester, which is mixed thoroughly with catalyst and activator is poured over it to prepare the composite.
- Treated Chopped fibers with different fibre loadings 5%, 10% and 15% is placed on the mold surface and unsaturated polyester, which is mixed thoroughly with catalyst and activator is poured over it to prepare the composite.
- Treated Chopped fibers with different fibre loadings 5%, 10% and 15% is placed on the mold surface and the CNT/polyester matrix solution with different percentages of CNT (0.2%, 0.4% and 0.6%) mixed with activator and catalyst is poured on the fibers to prepare the composite.

RESULTS AND DISCUSSION

Tensile Strength

Figure 1 shows the variation in the tensile strength of jute fibre/ carbon nanotube reinforced polyester composites with percentage variation in filler loading for untreated, alkali treated and treated jute fibre reinforced with three different percentage of carbon nanotube filler. There is marginal increase in the tensile strength with increase in jute fibre loading for untreated fibre, indicating inadequate interfacial adhesion between fibre and matrix resulting in poor load transfer from matrix to fibre. For alkali-treated fibers from jute, the tensile strength increases as the percentage of fiber loading decreases. Higher fiber loading results in a faster rate of growth, suggesting that the strengthening power of fiber is more prevalent at greater weight levels. Also, the rise in the tensile strength is higher for treated fibre compared to untreated fibre as a result of better interfacial adhesion between fibre and matrix due to alkali treatment. There is an increase in the tensile strength for jute fibre/carbon nanotube polyester composites with increase in fibre loading with addition of 0.2%, 0.4% and 0.6% of carbon nanotube filler.

Polymer-carbon nanotube interface is critical for enhancing the properties of polymer composites [46] and increase in the tensile strength can be attributed to strong interface and better dispersion of carbon nanotube in polymer matrix and is supported by SEM images [33, 47]. The tensile strength of polymer composite is higher with carbon nanotube and this can be due to high strength of carbon nanotube as a result of large interfacial area because of its nano size dimensions [20]. The rate of increase is higher at 15% fibre loading for 0.2% and 0.4% fibre loading, again indicating reinforcing effect at higher loading. The increase in the tensile strength is maximum for 0.6% carbon nanotube filler. Also, at any given fibre loading the tensile strength is maximum for 0.6% carbon nanotube filler loading.

Flexural Strength

Figure 2 shows the variation in the flexural strength of jute fibre/ carbon nanotube reinforced polyester composites with percentage variation in filler loading for untreated, alkali treated and treated jute fibre reinforced with three different percentage of carbon nanotube filler. For untreated jute fiber studded polyester composites, the flexural strength first decreases at 5% fiber loading and then doubles at greater fiber packing.

Initial decrease can be attributed to insignificant contribution of fibre reinforcement at low fibre loading. For alkali-treated jute fiber the flexural strength increases as the fraction of fiber loading increases. Once

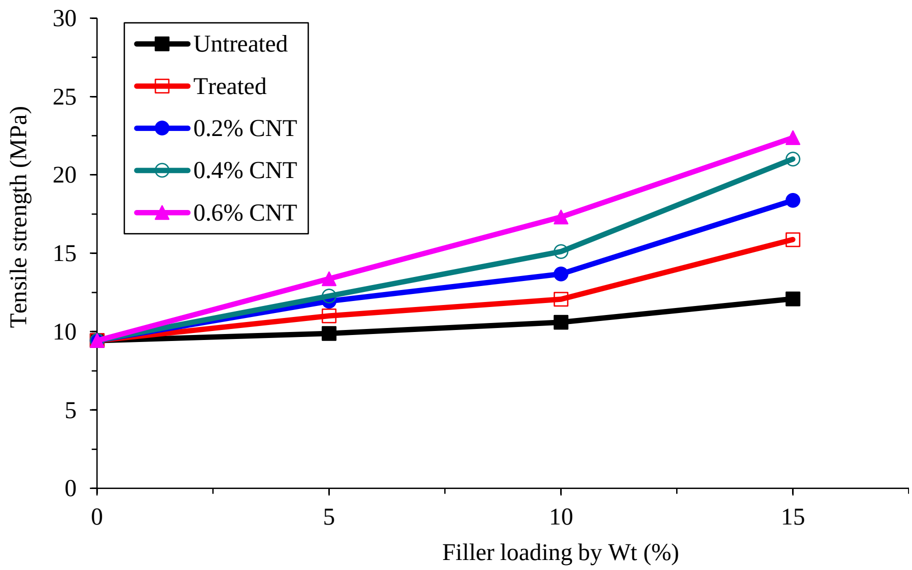

Figure 1. Variation in the tensile strength of jute fibre and carbon nanotube reinforced polyester composites.

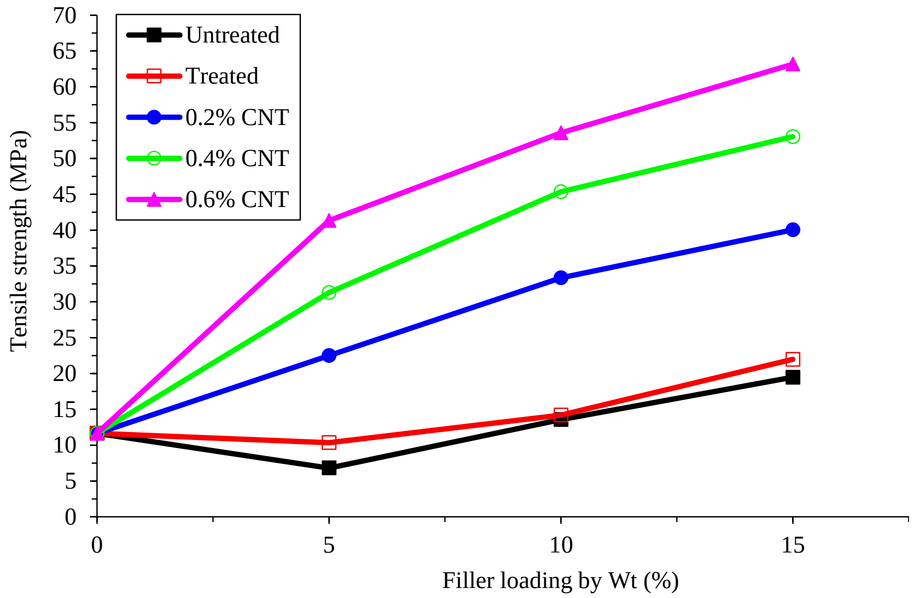

Figure 2. Variation in the flexural strength of jute fibre and carbon nanotube reinforced polyester composites.

more, the rate of growth increase with increasing fiber loading, suggesting that the reinforcing effect of fiber is more prevalent with greater doses.

There is an increase in the flexural strength for jute fibre/carbon nanotube polyester composites with increase in fibre loading with addition of 0.2%, 0.4% and 0.6% of carbon nanotube filler. The increase in the flexural strength can again be attributed to strong interfacial adhesion between jute fibre and carbon nanotube- polyester composites. Also, restriction of the polymer chain mobility under load due to carbon nanotube uniform dispersion leads to improvement in flexural strength [48]. The rate of increase is higher at 5% fibre loading for 0.4% and 0.6% carbon nanotube filler loading. The increase in the flexural strength is maximum for 0.6% carbon nanotube filler. Again, at any given fibre loading the flexural strength is maximum for 0.6% carbon nanotube filler loading.

Impact Strength

Figure 3 shows the variation in the impact strength of jute fibre/ carbon nanotube reinforced polyester composites with percentage variation in filler loading for untreated, alkali treated and treated jute fibre reinforced with three different percentage of carbon nanotube filler. As fiber loading rises the impact strength increases also.

For untreated and alkali treated jute fibre reinforced polyester composites, there is slight increase in impact strength at 5% fibre loading followed by higher increase in it at higher fibre loading indicating the reinforcing effect of fibre. Addition of CNT enhances the impact strength significantly and the rate of increase is maximum for 0.6% CNT composite. The increase in the impact strength can be attributed to strong interfacial adhesion and homogeneous dispersion as a result of fibre treatment [49]. Also, incorporation of carbon nanotube results in an increase in microcrack prevention resulting in an increase in the impact strength [50].

SEM Analysis

To understand the level of adhesion between the filler i.e., carbon nanotube-jute with the polymer matrix, the SEM micrographs of the samples were investigated. Figures 4 and 5 show the SEM micrographs of 0.2% and 0.4% carbon nanotube-jute fibre reinforced polyester composites. The properties of carbon nanotube reinforced polymer composites largely depend on the interfacial bonding

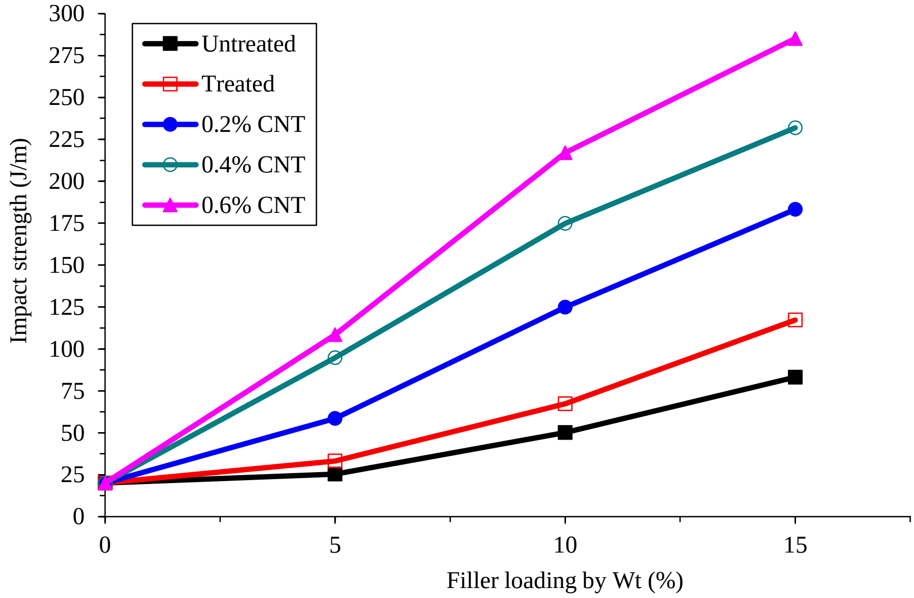

Figure 3. Variation in the impact strength of jute fibre and carbon nanotube reinforced polyester composites.

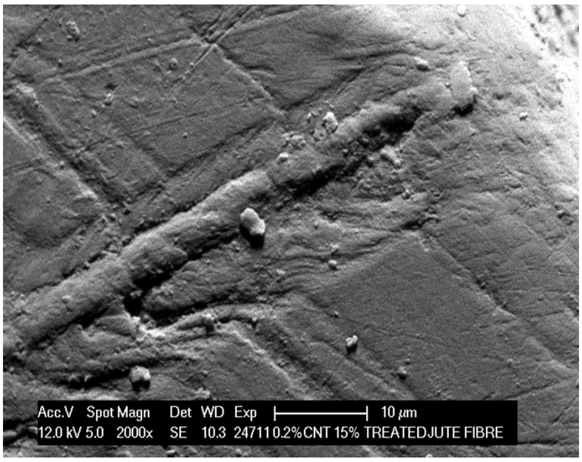

Figure 4. SEM image of 0.2% CNT plus 15% treated jute fibre reinforced polyester composites.

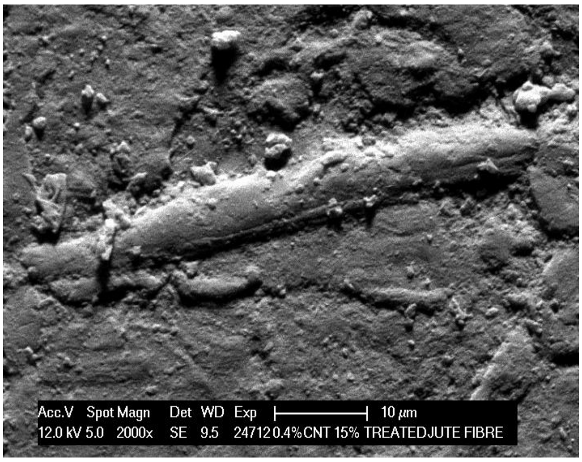

Figure 5. SEM image of 0.4% CNT plus 15% treated jute fibre reinforced polyester composites.

and strength at the interface. It can be observed from Figures 4 and 5 that the interfacial adhesion between the matrix and fiber is quite strong which implies enhanced mechanical properties of carbon nanotube-jute fiber reinforced polyester composite.

CONCLUSION

As fiber loading rises the tensile and impact strengths correspondingly increase. Increase in the tensile strength is higher for treated fibre as compared to untreated fibre. The increase is maximum for 0.6% carbon nanotube- jute fibre reinforced polyester composites. The torsional strength of the 0.2%, 0.4%, and 0.6% carbon nanotube-jute fiber polyester composite increases as the fiber loading increased. However, for both treated and untreated jute fiber reinforced polyester composites without carbon nanotube, the flexural strength drops up to 5% fiber loading, after which it increases at increasing fiber dosage.

Declaration of Conflicting Interest

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