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Study on Effect of Chemical Treatments and Concentration of Jute on Tensile Properties of Long & Continuous Twisted Jute/Polypropylene Composites

Gunti Rajesh, Atluri V. Ratna Prasad

Department of Mechanical Engineering, DVR & Dr. H S MIC College of Technology, Kanchikacherla, India.
Department of Mechanical Engineering, V R Siddhartha Engineering College, Vijayawada, India..

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A B S T R A C T

Thermoplastic based composites are now becoming popular due to their advantage in processing. On the other hand, jute is an annually regenerative, biodegradable, lignocellulosic bast fiber. The present study deals with evaluation of mechanical properties of continuous long twisted jute fiber reinforced polypropylene composites. The composite has been developed by injection molding process and hand-lay up technique. The effects of various chemical modifications on fiber like Mercerization (5%, 10% and 15% of NaOH), Neutralization and Bleaching with H_2O_2 have been studied. The composites were also prepared by adding different weight proportions of jute fiber bundles (2.5%, 5%, 7.5% & %10%). The highest tensile strength of 31.48MPa and maximum tensile modulus of 277.77MPa is obtained for 15% NaOH treated jute fiber reinforced composites with 10% weight fraction of fiber. There is a highest specific tensile strength of 0.0291 MPa/ kg/m^3 obtained for 15% NaOH treated and bleached jute fiber reinforced polypropylene composite with 10% weight fraction of fiber. The tensile strength and tensile modulus are increased with increasing the NaOH percentage in treated jute fiber reinforced PP composite. Also there is an increase in the tensile properties with increase in the %weight fraction of fibers in the polypropylene matrix. It is also observed that there is an increase in specific tensile strength and specific tensile modulus with increasing the NaOH percentage in treating the fibers. These properties are further increased with increase in % weight fraction of fiber in the composite. The properties of untreated jute fiber reinforced PP composite are decreased compared to plain PP and treated jute fiber reinforced composites.

Introduction

Recently due to improvement of people's living standards and need for environmental protection, the demand for natural biodegradable and eco friendly fibers is rising world wide day-by-day. Ligno cellulosic natural fibers such as flax, hemp, sisal and jute are an interesting, environmentally friendly alternative to the use of glass fibers as reinforcement in engineering composites. These fibers are renewable, non abrasive and can be incinerated for energy recovery since they possess a good calorific value and cause little concern in terms of health and safety during handling of fiber products [3]. In addition, they exhibit excellent mechanical properties, low density and are cheap. This environmentally friendly feature makes the materials very popular in the engineering markets such as automotive and construction industry. There are several reports about the use of jute as reinforcing fiber for thermosets and thermoplastics. In recent years natural fiber reinforced thermoplastics were receiving more attention because of issues of environmental protection. Jute fiber is a bast fiber obtained from the bark of jute plant containing three main categories of chemical compounds namely cellulose (58~63%), hemicellulose (20~24%) and lignin (12~15%) and some other small quantities of constituents like fats, pectins, aqueous extracts, etc. Jute fiber is composed of small units of cellulose surrounded and cemented together by lignin and hemi cellulose. Large amount hydroxyl group in cellulose gives natural fiber hydrophilic properties when used to reinforce hydrophilic matrices [1]. The result is a very poor interface and poor resistance to moisture absorption. Hemicellulose is strongly bound to cellulose fibrils presumably hydrogen bonds. Hemicellulosic polymers are branched, fully amorphous and have a significantly lower molecular weight than cellulose. Because of its open structure containing many hydroxyl and acetyl groups, hemicellulose is partly soluble in water and hygroscopic. Legnins are amorphous, highly complex, and mainly aromatic and have the least water sorption of the natural fiber components.

- Corresponding author: Gunti Rajesh
- E-mail address: rajesh.mtech@gmail.com
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Chemical treatments:

Because the low interfacial properties between fiber and polymer matrix often reduce their potential as reinforcing agents due to the hydrophilic nature of natural fibers, chemical modifications are considered to optimize the interface of the fibers. Chemicals may activate hydroxyl groups or introduce new moieties that can effectively interlock with the matrix. Generally, chemical coupling agents are molecules processing two functions. The first is to react with hydroxyl groups of cellulose and second is to react with functional groups of matrix. Chemical modifications of natural fibers aimed at improving the adhesion with a polymer matrix.

Alkaline treatment or mercerization:

It is one of the most used chemical treatments of natural fibers when used to reinforce thermoplastics and thermosets [3]. The important modification done by alkaline treatment is the disruption of hydrogen bonding in the network structure, there by increasing surface roughness [9]. These treatments remove certain amount of lignin, wax and oils covering the external surface of the fiber cell wall, depolymirizes cellulose and expose the short length crystallites. Addition of aqueous sodium hydroxide (NaOH) to natural fiber promotes the ionization of hydroxyl group to the alkoxide.

Fiber – OH+ NaOH→ Fiber – O – Na + H_2O

Bleaching with H_2O_2

Bleaching with H_2O_2 (6% purified) removes wax, fatty substances and lignin. Alkali treatments changes the colour of fibers from brown to dark brown and bleaching with H_2O_2 produce yellowish brown fibers indicating that expected modification might have achieved [6]. The quality of fibers produced using peroxide can be stored for long time

Experimental

Materials:

The retted jute fibers were purchased from the local market at Vijayawada city, India. The jute fibers were dipped in the water, dried and lightly combed. Aqueous NaOH and Acetic acid glacial (99-100%) for neutralization and H_2O_2 (6% purified) were purchased from National Scientific Research Ltd, Vijayawada. Polypropylene granules were purchased at Maram Polimers Pvt. Ltd, Vijayawada, India.

Jute fiber treatments- mercerization

All the retted fibers were washed with large amount of distilled water and dried at 50^{0}C until constant weigh, prior to treatment. The mercerization process consisted of immersing jute fibers (200g) in 5% (5g in one liter water), 10% and 15% NaOH solution for 6hrs at room temperature with occasional shaking and stirring followed by neutralizing with 50% acetic aid to remove any absorbed alkali.

Bleaching

Jute fibers (200g) were added to 6% hydrogen peroxide at room temperature and stirred for one hour and dried in the oven at 50^{0}C until it has reached a constant weight.

Sample preparation

The polypropylene thermoplastics granules were melted in the vertical injection molding machine with two heating zones set at. The weight of fibers in the composite was 20% of total weight of polypropylene. The samples of treated and untreated jute/PP composites were prepared by injecting the molten polypropylene into the mold as per ASTM Standard size. The treated and untreated fibers were cut to length of mold, twisted to make as a bundle and laid longitudinally throughout the mold on the top as per requirement. Sufficient pressure is applied on the sample to eliminate voids in the composite. They were air cooled at room temperature.

Tensile properties

Tensile strength (TS), tensile modulus (E) and elongation at break were determined according to ASTM- D638 under ambient conditions using A 2 ton capacity - Electronic Tensometer, METM 2000 ER-I model (Plate II-18), supplied by M/S Microtech Pune, with a cross head speed of 2mm/min. The reported values are the average of at least five sample measurements.

Results:

The alkali treatment changed the colour of fibers from brow to dark brown and bleaching with H_2O_2 produced yellowish brown fibers indicating that the expected modifications i.e. lignin, wax and fatty substances were removed.

Table 3.1: Effect of Chemical Modification

	Weight of Fiber (mg)	**Diameter of fiber(mm)**
Before fiber treatment	22.00	0.29
After fiber treatment (15% NaOH+ Bleaching with H_2O_2	17.30	0.23

The fiber diameter has reduced from 0.29mm to 0.23mm and weight has reduced from 22mg to 17.3mg. This is due to removal of cementing materials like lignin, pectin and hemicelluloses present in the cell wall. The ultimate tensile strength of 24.51MPa is obtained for plain polypropylene sample and the maximum strength obtained for untreated jute fiber reinforced composite is 24.52MPa at 2.5% weight fraction.

The maximum ultimate tensile strength of 31.48MPa was obtained for 15% NaOH treated and bleached jute fiber reinforced PP composite with 10% weight of jute fibers in the composite i.e. there is 27.2% increase in the strength. A value of 24.76MPa was obtained for 5% NaOH treated and bleached jute fiber reinforced PP composite with 2.5% weight of fibers in the composite which is also more than which obtained for composite with untreated fibers and without fibers.

It is seen that with increase in the fiber content in the composite and % of NaOH in the fiber treatment has increased the tensile strength. This may be due to rougher fiber topography resulting in effective interlocking of fibers with matrix material due to bleaching with H_2O_2. Alkali treatments separate the fibre bundles into elementary fibers by degrading the cementing materials like pectin, lignin and hemicelluloses thus increasing the surface area for bonding with matrix material.

There is a high tensile modulus of 277.7MPa for 15% NaOH treated jute fiber reinforced PP composite with 10% weight of jute fibers in the composite i.e. 26.7% more than plain PP and 61% more than untreated fiber reinforced composite. It is seen that with increase in the fiber content in the composite, the tensile modulus is also increased. This is due to the fact that the fibers possess much higher young's moduli than the matrix material.

The percentage elongation at break is reduced with increase in the fiber content and increase in the NaOH for fiber treatment. It may be due to reduction in the cellulosic content in the fiber after chemical modification.

It is observed that the specific tensile strength for 15%NaOH treated fiber reinforced PP composite with 7.5% weight fraction of fibers is 52.3% more than that is obtained for plain PP and 41% more than that is obtained for untreated fiber reinforced composite.

It is also observed that the specific tensile strength and specific modulus was increasing with increasing the NaOH percentage in treating the fibers and also with increase in the weight fraction of fibers in the composite. This may be due to reduction in the density of fiber hence overall density of composite.

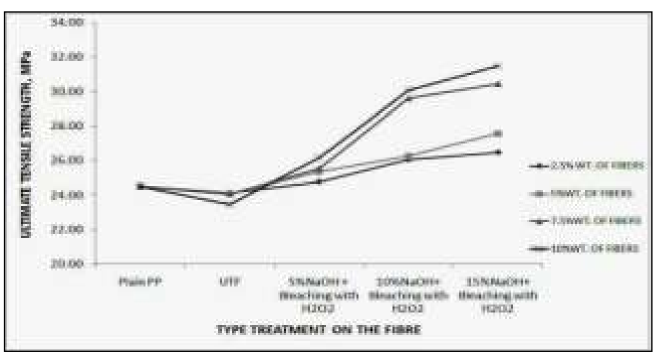

Figure 3.1: effect of chemical treatment and % wt. of fiber on Ultimate Tensile Strength of continuous long jute fiber reinforced PP composites

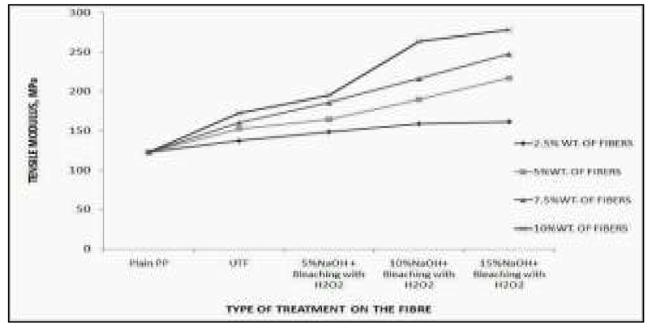

Figure 3.2: effect of chemical treatment and % wt. of fiber on tensile modulus of continuous long jute fiber reinforced PP composites

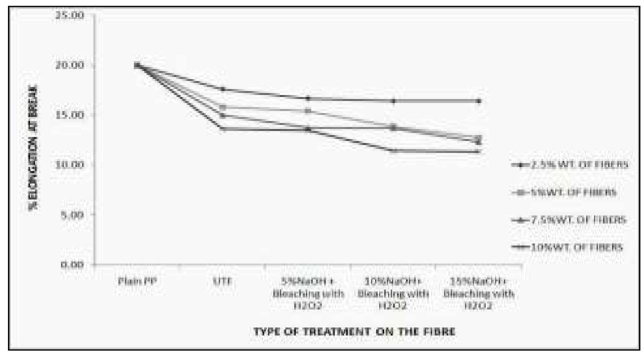

Figure 3.3: effect of chemical treatment and % wt. of fiber on %elongation at break of continuous long jute fiber reinforced PP composites

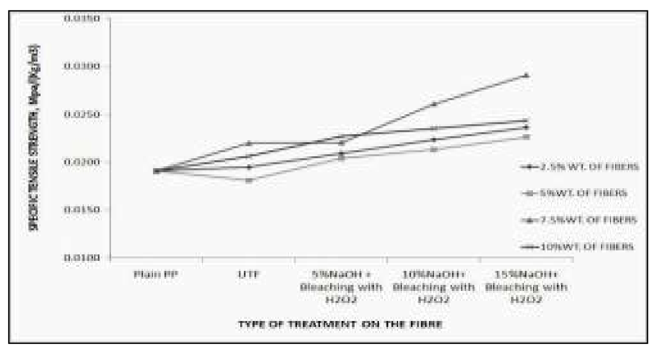

Figure 3.4: effect of chemical treatment and % wt. of fiber on specific tensile strength of continuous long jute fiber reinforced PP composites

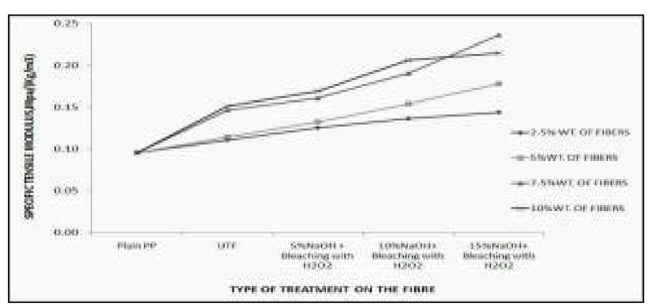

Figure 3.5: effect of chemical treatment and % wt. of fiber on specific tensile modulus of continuous long jute fiber reinforced PP composites

Conclusion:

The influence of fiber treatments by washing, mercerization and bleaching on the mechanical properties of the jute fiber reinforced polypropylene composites is analyzed.

Chemical treatments on the jute fiber have reduced the diameter and weight of the fiber compared with untreated fiber.

The tensile strength and tensile modulus are increased with increasing the NaOH percentage in treated jute fiber reinforced PP composite. Also there is an increase in the tensile properties with increase in the %weight fraction of fibers in the polypropylene matrix.

It is also observed that there is an increase in specific tensile strength and specific tensile modulus with increasing the NaOH percentage in treating the fibers followed by bleaching. These properties are further increased with increase in % weight fraction of fiber in the composite. The properties of untreated jute fiber reinforced PP composite are decreased compared to plain PP and treated jute fiber reinforced composites.

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