

Effect of Fibre Loading and Successive Alkali Treatments on Tensile Properties of Short Jute Fibre Reinforced Polypropylene Composites

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ABSTRACT: The use of natural fibres like flax, hemp, jute, kenaf, etc. in fibre-reinforced composites have increased now a days due to advantages like low density, low cost and biodegradability. But they have poor compatibility with the matrix and they have relatively high moisture sorption. Therefore different chemical treatments are done on the fibres to modify the surface. In this research, short jute fibre reinforced polypropylene composites have been developed by injection molding technique with varying parameters like fibre loading (0%, 5%, 10%, 15%, 20% & 25% by weight) and fibre condition (untreated, NaOH treated at 5%, 10% & 15% concentrations followed by bleaching with H_2O_2) at constant fibre length of 3mm. Then these composite specimens are tested for tensile strength. The results showed that tensile strength increases with increase in the fibre loading. However after 20% fibre loading with 10%NaOH concentration in the fibre treatment, the strength decreased again. There was small increase in the strength of composite with treated fibres compared to composite with untreated fibres. The modulus of the composite with treated fibres has increased considerably when compared to plain PP and untreated fibre reinforced PP composite.

KEYWORDS: Bleaching, Composite, Natural Fibre, Tensile Properties

I. INTRODUCTION

In recent years processing of thermoplastic composites using natural fibers as reinforcement has increased dramatically [1]. Due to the enhancement in the people's living standards and need for environmental protection, the demand for eco friendly and biodegradable fibres is increasing day by day. These fibres are renewable, non abrasive, and can be cremated for energy recovery as they possess a good calorific value and cause little concern in terms of health and safety during handling of fibre products. However they exhibit excellent mechanical properties, low density and low cost. These features made the materials very popular in engineering markets like automotive and construction industry [2][6].

There are several reports about the use of jute as reinforcing fibers for thermosets [7][9] and thermoplastics [10]. The studies of jute fiber composites were carried out mostly in India in early years and jute fiber reinforced thermosets had been the focus of studies. In recent years, natural fiber reinforced thermoplastics were receiving more and more attention because of issues of environmental protection. Fiber treatment and interfacial modification were most frequently studied issues aiming to improve the properties of short or long fiber reinforced composites.

Jute fiber is a bast fiber which is 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 [11]. 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. Lignin is amorphous, highly complex, and mainly aromatic and has the least water sorption of the natural fiber components.

II. CHEMICAL TREATMENTS:

Chemical modifications are considered to optimize the interface of the fibers as the low interfacial properties between fiber and polymer matrix often reduce their potential as reinforcing agents due to the hydrophilic nature of natural 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 [1]. Chemical modifications of natural fibers aimed at improving the adhesion with a polymer matrix.

(i) Alkaline treatment or mercerization:

The important modification done by alkaline treatment is the disruption of hydrogen bonding in the network structure, thereby increasing surface roughness [1]. It is one of the most used chemical treatments of natural fibers when used to reinforce thermoplastics and thermosets [2]. These treatments remove certain amount of lignin, wax and oils covering the external surface of the fiber cell wall, depolymerizes 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 [1][2].



(ii) Bleaching with H₂O₂:

Bleaching with H₂O₂ (6% purified) removes wax, fatty substances and lignin. Alkali treatments changes the colour of fibers from brown to dark brown and bleaching with H₂O₂ produce yellowish brown fibers indicating that expected modification might have achieved [12][13]. The quality of fibers produced using peroxide can be stored for long time. Bleaching will remove non-cellulosic substances (lignin) without significantly altering the extracted fibers [14].

III. EXPERIMENTAL PROCEDURE

2.1 Materials:

The semi 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 H₂O₂ (6% purified) were purchased from National Scientific Research Ltd, Vijayawada. Polypropylene granules were purchased at Maram Polymers Pvt. Ltd, Vijayawada, India.

2.2 Jute fiber treatments- mercerization

The semi retted fibers were dipped in the water for 1hour, dried at 50°C until constant weigh, lightly combed and cut to 3mm length prior to treatment [15]. The mercerization process consisted of immersing 200g of jute fibers in 5% (5g of NaOH in 100ml of water), 10% and 15% NaOH solution for 6hrs [2, 16] at 70°C temperature[11] with occasional shaking and stirring followed by neutralizing with 50% acetic acid to remove any absorbed alkali and finally washed thoroughly.

2.3 Bleaching

The treated Jute fibers (200g) were added to 10mL/L of 30% purified hydrogen peroxide at room temperature and stirred for 45minutes [14], washed with distilled water and dried in the oven at 50°C until it has reached a constant weight.

2.4 Composite Preparation

The PP granules were melted in the vertical injection molding machine with two heating zones. The samples are prepared by taking different weight proportions (0%, 5%, 10%, 15%, 20% & 25% by weight) of fiber content with PP matrix [17]. The samples of untreated and treated short jute fibre reinforced polypropylene composites were prepared by injection moulding technique as per ASTM Standard size. The samples were air cooled at room temperature. The samples are prepared and tested for tensile strength according to ASTM standards.

2.5 Tensile Test

Tensile tests were conducted according to ASTM D638 using a 2 ton capacity- Electronic Tensometer, METM 2000 ER-I model supplied by M/S Microtech Pune, with a cross head speed of 2mm/min. from the obtained load and elongation values, the tensile strength and modulus are calculated.

IV. RESULTS AND DISCUSSION

3.1. Tensile strength

From figure 3.1, it was observed that the tensile strength of composite increases with increase in the fibre loading up to 20% weight and then strength decreases with further increase in the fibre loading [17]. This result may be due to the fact that, the incorporation of fibres into thermoplastics leads to poor dispersion of fibres due to strong inter fibre hydrogen bonding which holds the fibres together. Improper adhesion obstructs the increment of tensile strength [18]. Thus as fibre percentage increases, gathering of fibers takes place instead of dispersion and melted polypropylene cannot wet the fibres due to non entrance of melt through the two adjacent fibres. Since there is more fibre-fibre interaction than fibre matrix interaction, failure occurs.

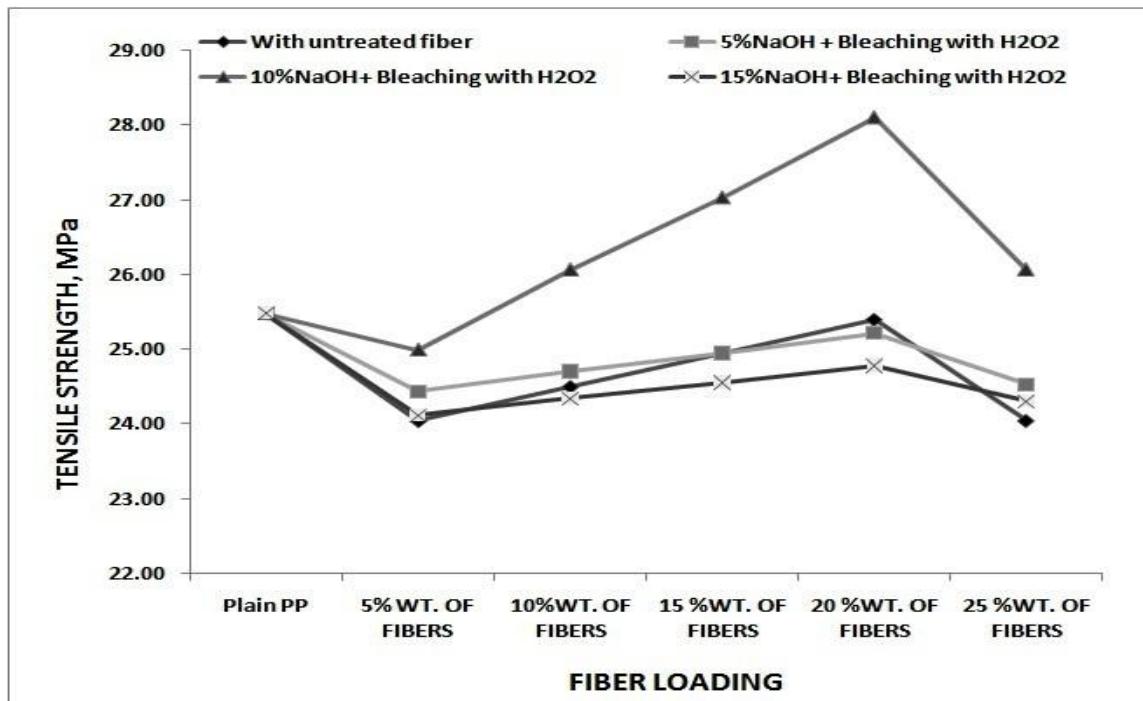


Figure 3.1: Variation of tensile strength of composite with fibre loading and alkali treatments on the fibre

From the figure 3.1, it was also observed that, the strength of composite was improved by alkali treatment [19][20]. A strong sodium hydroxide and H₂O₂ medium may remove lignin, hemi cellulose and other alkali soluble compounds from the surface of the fibres. This will increase the numbers of relative hydroxyl groups on the fibre surface available for chemical bonding. So strength should be higher than untreated fiber reinforced composites. The probable reason of this may be, alkali reaction on cementing materials of the fibre especially lignin and hemicellulose may leads to the splitting of fibres into fine filaments. As a result, wetting of fibers as well as bonding of fibres with matrix may improve and fibres become brittle. These fibres under stress break easily. Therefore they can not take part in the stress transfer mechanism [21]. So high concentration of sodium hydroxide may increase the rate of hemicellulose dissolution, which will finally lead to strength deterioration.

3.2. Percentage elongation at break

From figure 3.2, it was clear that the % elongation at break reduces with increase in fibre loading as well as with the concentration of NaOH in the fibre treatment [11]. The composite had lower elongation at break than PP matrix. This may be due to the reinforcement of polymer matrix with jute fibre [22].

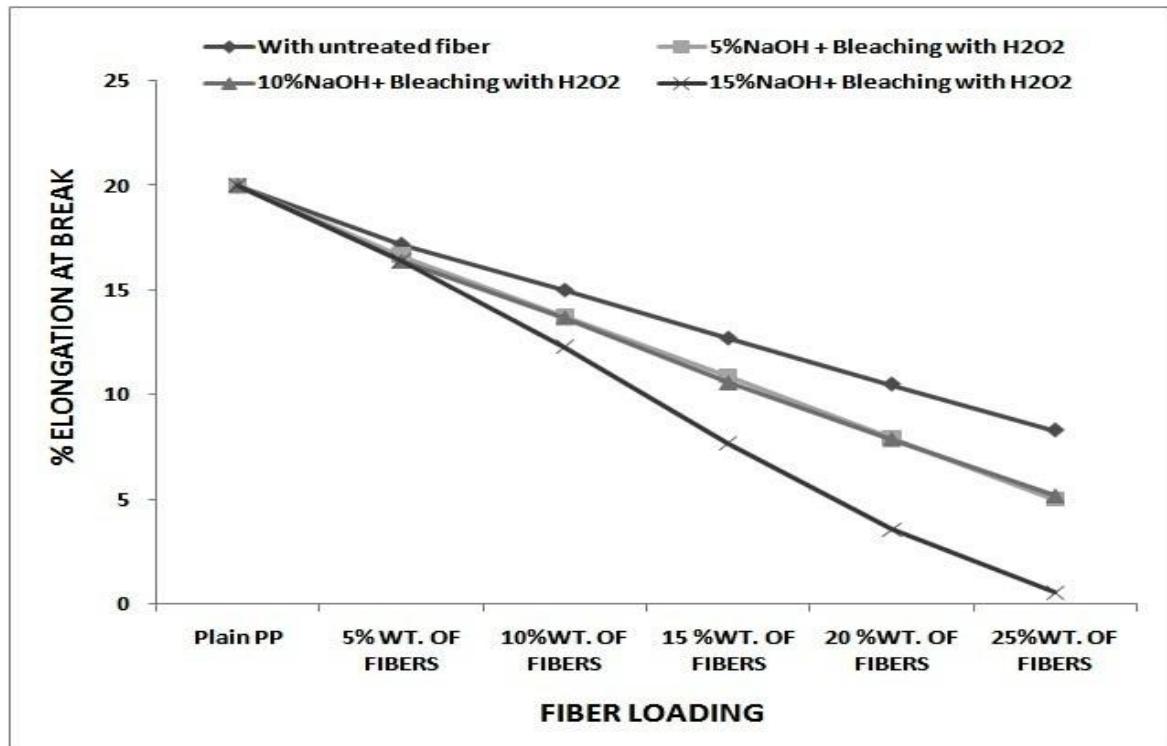


Figure 3.2: Variation of % elongation at break of composite with fibre loading and alkali treatments on the fibre

3.3. Tensile modulus

It is observed *from figure 3.3* that at 25% fibre loading the tensile modulus values were approximately 40% higher in case of raw jute fibre-PP, 55% higher in case of 5% NaOH Treated followed by H₂O₂ treatment on fibre-PP, 90% higher in case of 10% NaOH Treated followed by H₂O₂ treatment on fibre-PP and 100% higher in case of 15% NaOH Treated followed by H₂O₂ treatment on fibre-PP composites than PP matrix alone [22].

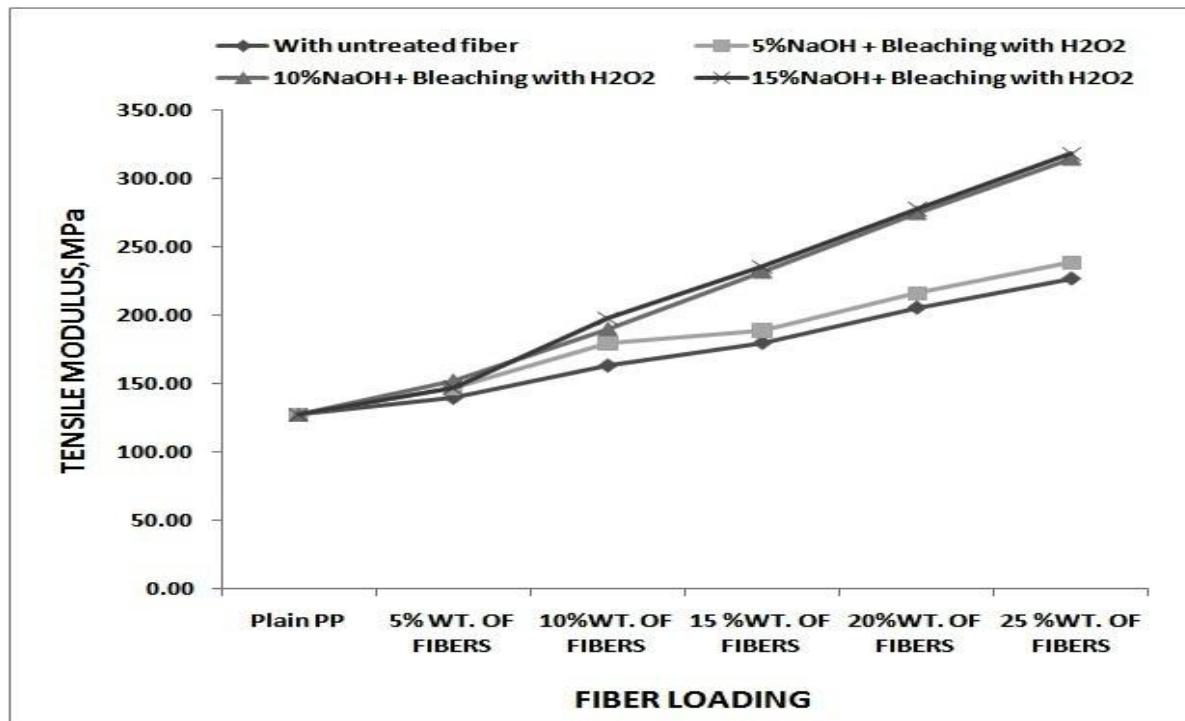


Figure 3.3: Variation of tensile modulus of composite with fibre loading and alkali treatments on the fibre

With the fibre treatment, the composite exhibited better interfacial bonding between the treated fibers and the matrix and hence reduced elongation so increased modulus.

V. CONCLUSIONS

- Bleaching with H_2O_2 after NaOH treatment has removed the non-cellulosic substances further. This was observed with change in the weight and diameter of fibre after the treatment.
- There was increase in the tensile properties of the composite with increase in the fibre loading up to 20% and then reduced.
- Also there was increase in the tensile strength of the composite with increase in the concentration of NaOH in the fibre treatment up to 10% compared to untreated fibre reinforced composite.
- The tensile modulus increases with increase in fibre loading as well as concentration of NaOH in the fibre treatment.
- There was a considerable decrease in the density of the composite when the fibres were treated and leads to increase in the specific tensile strength and modulus.

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