

Advanced Materials Manufacturing & Characterization

journal home page: www.ijammc-griet.com



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

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ARTICLE INFO

Article history:

Received: 11-06-2013

Accepted: 29-07-2013

Keywords:

Bleaching,
Composite,
Natural Fibre,
Tensile Properties

ABSTRACT

The use of natural fibres like flax, hemp, jute, kenaf, etc. as replacement to man made fibres in fibre-reinforced composites have increased now a days due to advantages like low density, low cost and biodegradability. But the natural fibres 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%, 7.5%, 10%, 12.5% & 15% by weight) and fibre condition (untreated, NaOH treated followed by bleaching with H₂O₂) 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 and also with increase in %NaOH (5%, 10% & 15%) concentration in the treatment followed by bleaching with H₂O₂. However after 10% 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

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 hemicellulose. 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.

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• Doi: <http://dx.doi.org/10.11127/ijammc.2013.07.12>

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, there by 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].

Fiber - OH + NaOH → Fiber - O - Na + H₂O + impurity

(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].

2. 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 500C 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 700C 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 500C 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 (5%, 7.5%, 10%, 12.5% & 15%) 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. As the density of the composite is known, the specific tensile strength and modulus are also calculated.

3. Results and Discussion

3.1 Diameter change and weight loss

The diameter of the fibres is obtained from tool makers microscope and the weight of the fiber is measured from the digital common balance provide with vacuum. Ten fiber samples of each proportion are taken and average of ten is tabulated below. The alkali treatment changed the colour of fibers from brow to dark brown and bleaching with H₂O₂ 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 on weight and diameter of the fiber

	Weight of fibre (mg)		Diameter of the fiber, μ m	
	Before Bleaching	After Bleaching	Before Bleaching	After Bleaching
Without treatment	22	22	2.9	2.9
5% NaOH Treatment	20.1	18.5	2.8	2.6
10% NaOH Treatment	18.4	16.9	2.6	2.4
15% NaOH Treatment	17.3	16.3	2.5	2.3

Table 3.1 shows that the fibre treatment with NaOH has reduced the fibre diameter from 2.9microns to 2.5microns 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. Further bleaching with H2O2 has reduced the diameter to 2.3microns and weight to 16.3mg which indicates that there is further removal of cementing materials like lignin has taken place.

3.2. Tensile strength

From figure 3.1, it was observed that the tensile strength of composite increases with increase in the fibre loading up to 10% 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.

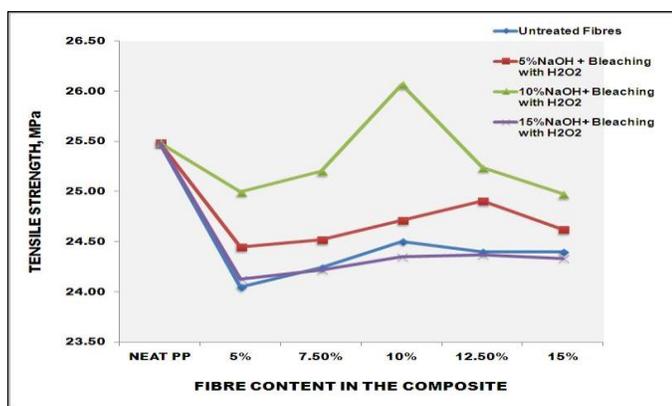


Figure 3.1: Variation of tensile strength of composite with fibre loading and alkali treatments on the fibre.

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, hemicellulose 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. 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]. It is observed from figure 3.3 that at 15% 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].

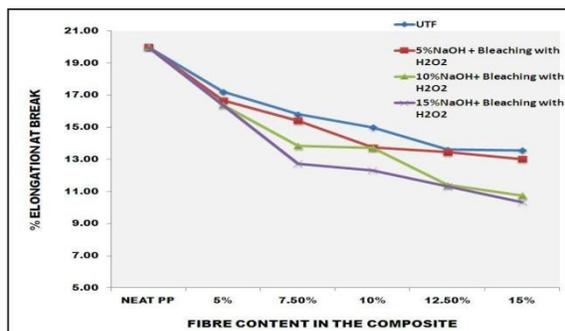


Figure 3.2: Variation of % elongation at break of composite with fibre loading and alkali treatments on the fibre.

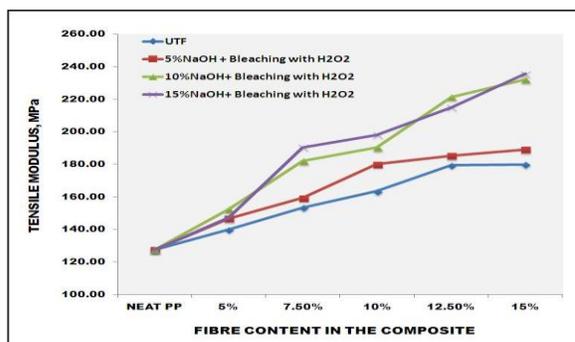


Figure 3.3: Variation of tensile modulus of composite with fibre

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

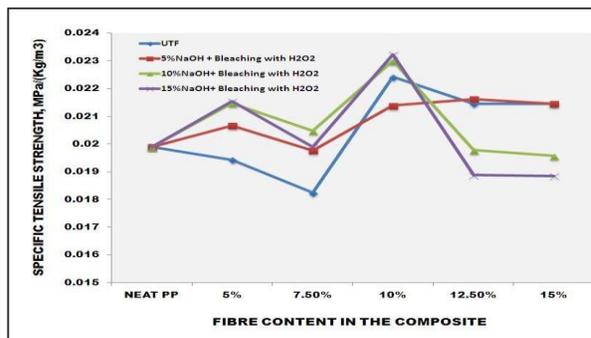


Figure 3.4: Variation of specific tensile strength of composite with fibre loading and alkali treatments on the fibre.

Table 3.2. Densities of Various Composites in(kg/m³):

S.NO	TREATMENT	PLAIN PP	95%PP+ 5%FIBERS	92.5%PP+ 7.5%FIBERS	90%PP+ 10%FIBERS	87.5%PP+ 12.5%FIBERS	85%PP+ 15%FIBERS
1	Untreated	1283.33	1237.61	1329.34	1092.99	1137.09	1137.09
	Fibres						
2	5%NaOH + H ₂ O ₂		1182.91	1240.46	1155.56	1151.71	1151.71
3	10%NaOH + H ₂ O ₂		1164.1	1230.77	1133.33	1276.07	1276.07
4	15%NaOH + H ₂ O ₂		1119.66	1217.09	1047.86	1291.03	1291.03

Table 3.2 shows the variation of densities of composites with fibre loading and fibre treatments. It was observed that the density of the composite with 10% fibre loading and 15% NaOH treated fibres in the composite.

Figure 3.4 show that the specific tensile strength of 15% NaOH Treated followed by bleaching with H₂O₂ fibre reinforced composite at 10% fibre loading was his compared to neat PP and composite with untreated fibres as the density of the composite was very low.

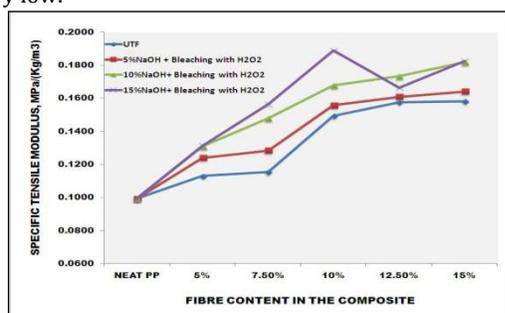


Figure 3.5: Variation of specific tensile modulus of composite with fibre loading and alkali treatments on the fibre.

Figure 3.5 shows that the specific tensile modulus of the composite increased with increase in the fibre loading and also with increase in the concentration of NaOH in the fibre treatment followed by bleaching with H₂O₂ due to reduction in the density as well as elongation at break values.

4. Conclusions

- Bleaching with H₂O₂ 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 10% 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.

References

1. Xue Li & Lope G. Tabil & Satyanarayan Panigrahi: Chemical Treatments of Natural Fiber for Use in Natural Fiber-Reinforced Composites: A Review: *J Polym Environ* (2007) 15:25–33.
2. X. Y. Liu, G. C. Dai.: Surface modification and micromechanical properties of jute fiber mat reinforced polypropylene composites: *eXPRESS Polymer Letters* Vol.1, No.5 (2007) 299–307
3. Eastham J. : Natural fibres for the automotive industry in ‘Seminar of The Alternative Crops Technology Interaction Network, Manchester, UK’ 16, 142–146 (2001).
4. Han S. O., Defoort B., Drzal L. T., Askeland P. A.: Environmentally friendly biocomposites for automotive applications in ‘33rd ISTC Conference, Seattle, USA’ 33, 1466–1477 (2001).
5. Marsh G.: Next step for automotive materials. *Materials Today*, 6, 36–43 (2003).
6. Chen Y., Chiparus O., Sun L., Negulescu I., Parikh D. V., Calamari T. A.: Natural fibers for automotive nonwoven composites. *Journal of Industrial Textiles*, 35, 47–62 (2005).
7. Gassan J., Bledzki A. K.: Possibilities for improving the mechanical properties of jute/epoxy composites by alkali treatment of fibres. *Composites Science and Technology*, 59, 1303–1309 (1999).
8. Gassan J., Bledzki A. K.: Effect of cyclic moisture absorption desorption on the mechanical properties of silanized jute-epoxy composites. *Polymer Composites*, 20, 604–611 (1999).
9. Gassan J., Gutowski V. S.: Effects of corona discharge and UV treatment on the properties of jute-fibre epoxy composites. *Composites Science and Technology*, 60, 2857–2863 (2000).
10. Karmaker A. C., Youngquist J. A.: Injection moulding of polypropylene reinforced with short jute fibers. *Journal of Applied Polymer Science*, 62, 1147–1151 (1996).
11. Wei-ming Wang; Zai-sheng Cai; Jian-yong Yu: Study on Chemical Modification Process of jute. *Journal of Engineering fibers and fabrics* Volume 3, Issue 2, 2008.
12. Mohd Zuhri Mohamed Yusoff; Mohd Sapuan Salit; Napsiah Ismail; Riza Wirawan: Mechanical Properties of short random oil palm fiber reinforced epoxy composites. *Sains Malaysiana* 39(1)(2010): 87-92.
13. Morsyleide F. Rosa, Bor-sen Chiou, Eliton S. Medeiros: Effect of fiber treatments on tensile and thermal properties of starch/ethylene vinyl alcohol copolymers/coir biocomposites: *Bioresource Technology* 100 (2009) 5196–5202.
14. Amel El Ghali, Imed Ben Marzoug: Separation and characterization of new cellulosic fibers from the *Juncus acutus* L Plant: *Bio Resources* 7(2), 2002–2018, 2002.
15. Md Nuruzzaman Khan, Juganta K. Roy, Nousin Akter, Haydar U. Zaman: Production and Properties of Short Jute and Short E-Glass Fiber Reinforced Polypropylene-Based Composites: *Open Journal of Composite Materials*, 2012, 2, 40–47.
16. Dipa Ray, B K Sarkar, A K Rana And N R Bose: Effect of alkali treated jute fibres on composite properties: *Bull. Mater. Sci.*, Vol. 24, No. 2, April 2001, pp. 129–135.
17. H.M.M.A Rashed, M.A. Islam and F.B. Rizvi: Effects of process parameters on tensile strength of jute fiber reinforced thermoplastic composites. *Journal of naval architecture and merine engineering*, 3(2006) 1-6.

18. Beckerman G.W., Pickering, K.L., and Foreman, N.J.: The Processing, Production and Improvement of hemp fibre reinforced polypropylene composite materials: proceedings of SPPM, 25-27 Feb. 2004, pp 257-265.
19. Dieu, T.V., Phai L.T., Ngoc P.M.: Study on preparation of polymer composites based on polypropylene reinforced by jute fibers: JSME International journal, Series A: Solid mechanics & Material engineering, Vol. 47, No.4, pp 547-550.
20. Razera I.A.T., and Frollini, E.: Composites based on jute fibers and phenolic matrices: Properties of fibers and composites: Journal of applied polymer science Vol.91, No.2, pp 1077-1085.
21. Ray D., Sarkar B.K., Rana A.K., Bose N.R.: Effect of alkali treated jute fibres on composite properties, Bulletin of materials science, Vol.24, No.2, pp. 129-135.
22. M Alamgir Kabir, M. Monimul Huque: Mechanical Properties of Jute fibre reinforced Polypropylene composite: effect of benzenediazonium salt in alkaline medium: bio resources 5(3), 1618-1625.
23. S Jayabal, S Sathiyamurthy, K T Loganathan And S Kalyanasundaram. Effect of soaking time and concentration of NaOH solution on mechanical properties of coir-polyester composites: Bull. Mater. Sci., Vol. 35, No. 4, August 2012, pp. 567-574.