CHEMICALLY TREATED SACCHARUM AS REINFORCEMENT FOR POLYESTER COMPOSITE

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Received on 07 June 2016 Accepted on 10 November 2016

Abstract

This work involves using *Saccharum* short fibers as reinforcement for unsaturated polyester before and after chemical treatment for fibers. The chemical treatment was done in NaOH solution with different concentrations include 0.125, 0.25, 0.375, 0.5 and 0.625 M at room temperature.

The prepared composites were characterized by FTIR spectra to confirm the improvement of interaction between reinforcement and matrix through the reduction in hydrophilic groups. The investigation by FTIR showed the improving of the adhesion between reinforcement and polyester as matrix because of reduction of absorption the water. The impact toughness was tested for polymeric composites and the results indicated that the chemical treatment with NaOH led to increasing impact energy due to increasing bonding force between treated *Saccharum* fibers and matrix.

Keywords: Natural fiber; Unsaturated polyester; Saccharum; Impact propertiy.

Introduction

Natural fibers have a wide range to use as reinforcement in engineering composites because of their environmentally friendly nature. These lignocellulosic natural fibers include flax, Grewia optiva, Pine needles, Hibiscus sabdariffa etc.. Suitable matrix materials for natural-fiber reinforced polymers are polymer resin systems such as thermoplastics and thermosetting. Polymer composites can be used in many different forms ranging from structural composites in the construction industry to the high technology composites of the aerospace, space satellite and many other industries (Kaith et al., 2005).

Saccharum fibers contain cellulose; lignin fills the spaces in the cell wall between cellulose, hemicellulose, and pectin components. It is covalently linked to hemicellulose and therefore cross-links different plant polysaccharides, conferring mechanical strength to the cell wall and by extension the plant as a whole. Lignin plays a crucial part in conducting water in plant stems. The polysaccharide components of plant cell walls are highly hydrophilic and thus permeable to water, whereas lignin is more hydrophobic. The cross-linking of polysaccharides by lignin is an obstacle for water absorption to the cell wall.

Many authors highlighted on adding natural fibers to polymer matrix composites (PMC) such as Palm and carbon fibers with weight fractions (10, 20, 30, 40, 50, and 60%), the maximum tensile strength and impact strength obtained with 60 wt% of fibers (Ali, 2012). Banana and coconut hush fibers also used before and after chemical treatment (which represented an effective way to clean the fiber surface), this treatment modified the surface and increased the surface roughness (Nor et al., 2009). On the other hand, the fiber treatment improved the mechanical properties of poly-(lactic acid) /bleached kenaf fiber composites (Nur et al., 2014). Unsaturated polyester resin as a matrix reinforced by natural jute fiber with different volume fraction (3%, 4%, 5%, 6%) were studied and the results showed that the increasing volume fraction of jute fibers led to increase bending modulus of elasticity, flexural strength and shear stress (Jawad et al., 2014). The characterization of untreated and treated fibers almost achieved by FTIR spectra (Elzbieta et al., 2001 and Volkan et al., 2008). Others researchers focused on studying mechanical properties of polymer matrix composites such as impact, hardness and bending (Bushra, 2014). The tensile, compressive strength and wear resistance were studied for PMC reinforced by *Saccharum* cilliare fibers (Singha and Vijay, 2009). Also tensile and flexural were tested for PMC reinforced by Alfa (Benyahia, 2013). Tensile, elongation, bending, hardness and impact for polymer matrix composites also investigated (Daiane et al., 2013; Oladele et al., 2010 and Waleed et al., 2010).

This present research aims to study the reinforcement by *Saccharum* short fibers on impact strength of unsaturated polyester. The *Saccharum* fibers were chemical treated with five concentrations of NaOH (0.125, 0.25, 0.375, 0.5 and 0.625 M) to investigate the effect of treated fibers on impact property. The characterization of bonding between fibers and matrix was done by FTIR spectra.

Experimental Procedure

Materials

The matrix system in the present study is the unsaturated polyester which representing thermosetting polymer. This polymer is transparent viscous liquid at room temperature which is a thermally hardened polymer (Thermosets). The properties of this polymer are listed in Table (1). To prepare polymer matrix, 2 gm of hardener was added to each 100 gm of unsaturated polyester.

Saccharum fibers were collected, washed with distilled water and dried in an air oven at 60°C for 10 h and kept for preparation of composites (Singha and Vijay, 2008). These fibers used as short- fibers with ≈ 1 cm in length as shown in Fig. (1). The chemical composition of this fiber was 45.5% cellulose, 27% hemicelluloses, 21.1% lignin, 4.6% extractives and 2.2% ashes, as weight percent.

Chemical Treatment of Saccharum

Sodium hydroxide was used for chemical treatment with five concentrations include 0.125, 0.25, 0.375, 0.5 and 0.625 M at room temperature. The molarities of these solutions were prepared by dissolving certain weight of sodium hydroxide (M.wt. 40 gm/mol and purity 99%) in 100 ml of distilled water with volumetric flask. This treatment was achieved by immersion the short fibers in alkaline solution for 48 hrs.

Preparation of composites

Randomly oriented fiber reinforced composites were prepared by taking different dimensions of the Saccharum fibers and add them to matrix composite. The mixture was very well mixed to maintain the uniformly distribution and then poured in to the molds. Cast iron molds with dimensions of (191×13×5 mm) and (80×10×5 mm). The inner surfaces of molds were coated with Vaseline to avoid adhesion of the mixture and to allow easy removal of the composites. The prepared samples were left in the mould for (24) hrs. at room temperature for curing.

FTIR Spectra

After preparation of composites, they characterized by FTIR. The FTIR spectra were recorded in Bruker Tensor 27 Fourier Transform Infrared Spectrophotometer for polyester and six *Saccharum* fibers reinforced polyester composites. This test was done at University of Technology – Department of Materials eng. In this test, transmission measurements require a short pathlength, and this can be obtained by pressing the sample into the devise. The measuring polymer spectra is attenuated total reflectance (ATR), in which the sample is pressed against a diamond and the absorption of the evanescent wave is measured. This technique requires little to no sample preparation and very reliably produces high quality spectra.

Impact Testing

Prepared composites were cut into rectangular pieces of dimension (80×10×5) mm for the evaluation of impact property according to ASTM D-256 at room temperature. The Izod impact test on specimens was determined using pendulum impact testing machine. It is made in New York, USA. Hammers with (5 Jules) fracture energy are used. The result was taken as an average for three records.

Results and Discussion

Chemical Treatment of Saccharum

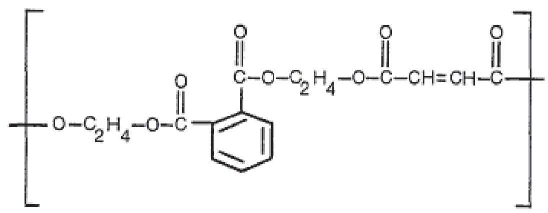
Lignin makes it possible for the plant's vascular tissue to conduct water efficiently. Alkaline treatment or mercerization is one of the best used chemical treatments for natural fibers (Rakesh et al., 2011). This treatment increases the amount of amorphous cellulose at the expense of crystalline cellulose, and then the hydrogen bonding will remove in structure as shown in the following reaction:

$$\textit{Saccharum Fiber} + NaOH \rightarrow \textit{Saccharum Fiber}O^{-}Na^{+} + H_2O$$

The poor compatibility between fiber and matrix is the main disadvantages of natural fibers in composites in addition to the relative high moisture sorption. Therefore, chemical treatments lead to modify the fiber surface properties. The chemical treatment of fiber improves the adhesion between the fiber surface and the polymer matrix and also increases fiber strength. Where water absorption is reduced and mechanical properties are improved in produced composite.

Characterization by FTIR

FTIR spectra were used to characterize the improvement of adhesion between the fiber surface and the polymer matrix. Figure (2) shows the FTIR spectrum of unsaturated polyester. Many peaks were appeared in this figure such as aliphatic, aromatic and vinyl CH stretching at 2850.08 to 2955.28 cm^{-1}. The peak at 1716.37 cm^{-1} is attributed to C=O stretching conjugated with C=C. While C–O stretching appears at 1253 cm^{-1}. CH_2 group appears at 1400.86 cm^{-1} and =CH aromatic (OOP) appears in the range of 600 to 875.69 cm^{-1}. The main groups in polyester are shown in the following structure.



Chemical structure of unsaturated polyester.

FTIR spectra of *Saccharum* fibers reinforced polyester composites with untreated and alkali treated fibers are shown in Fig. (3). In this figure, we can seen a peak at (1733.3) cm^{-1} which attributed to the presence of lignin (Bessadok et al., 2007). Also the peak at 1463.03 cm^{-1} is attributed to the CH_2 bending of cellulose. While the peak of C=O stretch for acetyl group in lignin appears at 1253.19 cm^{-1} which was reduced after chemical treatment. This was due to the partial removal of lignin from the fiber surface.

Alkali treatment by NaOH solution may be led to reduce the hydrogen bonding of hydroxyl groups in cellulose by removing the carboxyl group (Boopathi et al., 2012). This means that the numbers of hydroxyl groups (OH) were decreased and part of lignin was removed from the fiber.

Impact Property

The chemical treatment of *Saccharum* fibers improves the bonding at reinforcement/matrix interface and then improving the fiber-matrix interaction was done. These treatments led to improve impact property of produced composites, since the alkali treatment is disrupt the hydrogen bonding in the fiber surface which lead to get a better incorporation of fiber with the matrix.

Figure (4) shows the relation between impact strength and concentration of alkaline as a solution of chemical treatment. This figure indicates the increasing of impact energy with increasing concentration of NaOH solution. This increasing may be related to decrease of voids and defect in addition to good adhesion (interface) between the *Saccharum* fibers and polyester resin (matrix). The maximum impact energy was 0.24 J for polyester based composite reinforced with *Saccharum* short fibers treated by 0.625 M NaOH.

Conclusion

Saccharum short fibers were used as reinforcement for unsaturated polyester composites before and after chemically treatments with five concentration of NaOH solution include 0.125, 0.25, 0.375, 0.5 and 0.625 M. FTIR spectroscopy was used to characterized the effect of chemical treatment on fibers, this technique indicated the removing of non-cellulosic components from fibers and this is suggesting the increasing of the fiber-matrix interaction. Impact test also investigated for prepared composites and the results showed that the chemical treatments of fibers led to increasing impact energy with increasing NaOH concentration of treatment.

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Table (1) Properties of unsaturated polyester.

Density gm/cm^3	*Tensile strength MPa*	*Fracture toughness MPa.m$^{0.5}$*	*Percent elongation EL%*	*Thermal conductivity W/m.^{o}C*
1.255	70.3-103	0.6	<2.6	0.17

Fig. (1) Preparation *Saccharum* short fiber for chemical treatments.

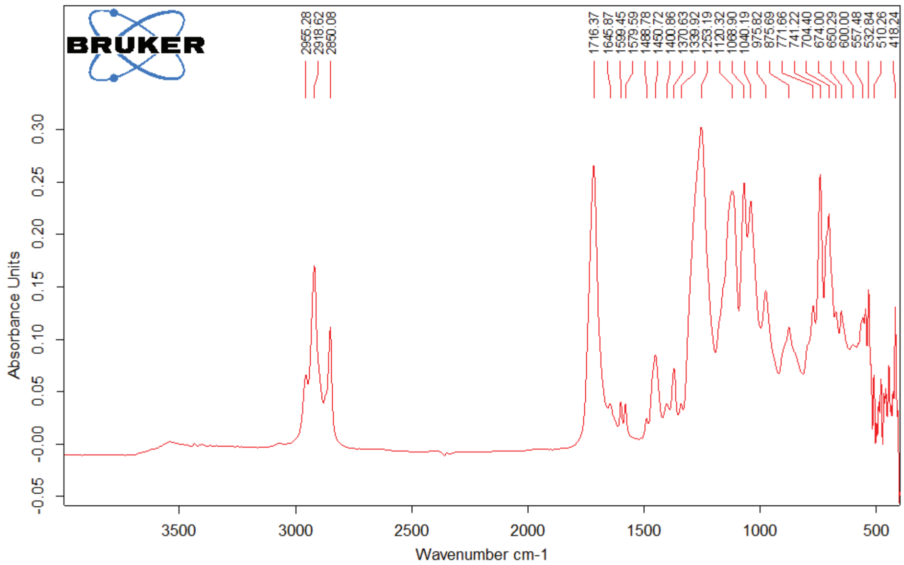

Fig. (2) FTIR spectrum of unsaturated polyester.

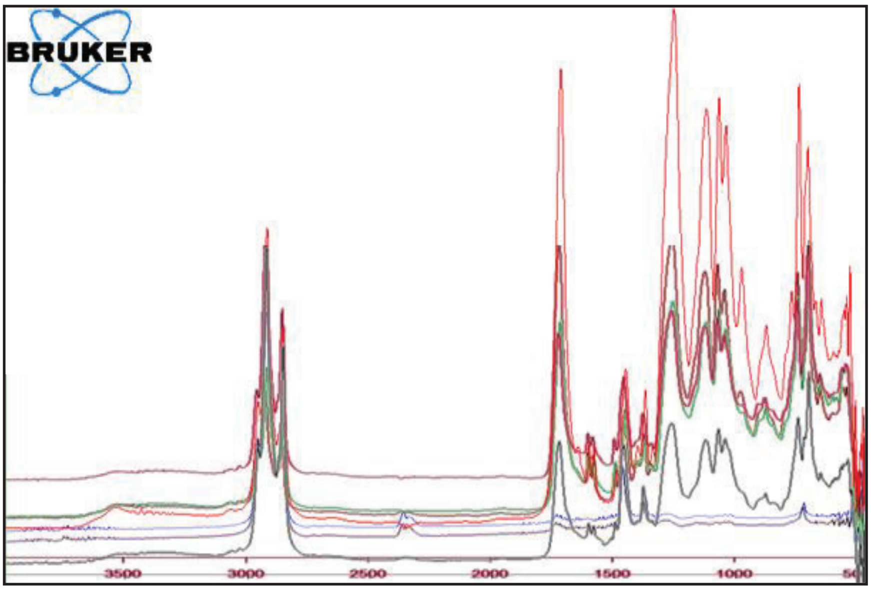

Fig. (3) FTIR for all samples; polyester (blue), composite with untreated fibers (red), composite with treated fiber in 0.125M NaOH (dark red), 0.25M (green), 0.375M (purple), 0.5M (pink) and 0.625M (black).

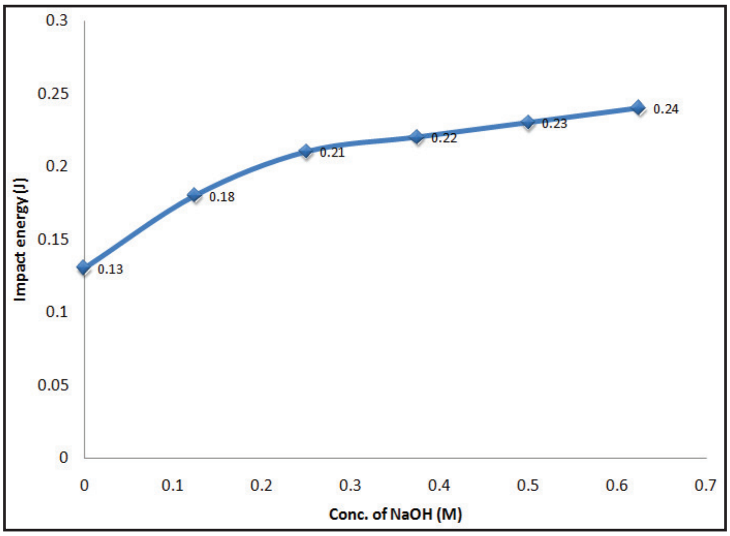

Fig. (4) Relation between impact strength and chemical treated fiber with different concentrations of NaOH solution.