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The Effect of Surface treatment on the Properties of Woven Banana Fabric based Unsaturated Polyester Resin Composites.

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Abstract: The aim of this paper is to study the effect of silane treatment on woven banana fabric based unsaturated polyester resin composites. The fabric was treated with vinyl triethoxysilane. Woven banana fabric (WBF) reinforced unsaturated polyester resin (UPR) composites were fabricated by hand lay-up technique. The fabric content in the composite was kept constant to 35 %. The variation in the mechanical properties (Tensile and Flexural strength) and water absorption were studied. Fourier transforms infrared spectroscopy (FT-IR) was utilized to characterize the chemically modified fibers. Reduction in water absorption of silane treated WBF/UPR composite was observed. The improved fiber–matrix interaction after silane treatment is evident from the enhanced tensile and flexural properties.

Keywords: woven banana fabric, silane, unsaturated polyester resin, mechanical properties, water absorption, fourier transforms infrared spectroscopy.

1. Introduction

Synthetic polymer composite materials are currently widely used in many industrial areas to meet light-weight and high strength requirements. However, with the increasing amount of synthetic polymer materials present worldwide, environmental issues such as disposal treatment, waste disposal services, and incineration pollution are becoming increasingly important [1,2]. Compared with synthetic fibers, the advantages of using natural fibers in composites are their low cost, low density, unlimited availability, biodegradability, renewability, and recyclability [3-4]. Some of the problems associated with untreated natural fiber-reinforced matrix composites include poor interfacial adhesion between the cellulose fibers and the resin matrix [5]. All plant-derived cellulose fibers are polar and hydrophilic in nature, mainly as a consequence of their chemical structure.

Natural fibres have a good potential for chemical treatment due to presence of hydroxyl groups in lignin and cellulose. Reaction of hydroxyl groups can change the surface energy and the polarity of the natural fibres. Many studies have been undertaken to modify the performance of natural fibres. Different surface treatment methods such as mercerization (alkali treatment), isocyanate treatment, acrylation, benzoylation, latex coating, permanganate treatment, acetylation, silane treatment and peroxide treatment have been applied on the fibre to improve its strength, size and its shape and the fibre-matrix adhesion.

Khashabaa and Seif et al. [6], the usage of woven composites has increased over the recent years due to their lower production costs, lightweight, higher fracture toughness and better control over the thermo mechanical properties. The weaving of the fiber provides an interlocking that increases strength better than can be achieved by fiber matrix adhesion. Failure of the composite will require fiber breakage, since fiber pullout is not possible with tightly woven fibers [7].

Rajesh Ghosh et al. [8] studied effect of fibre volume fraction on the tensile strength of Banana fibre reinforced vinyl ester resin composites. There was an improvement in the tensile properties of the banana fiber – vinyl ester resin composites. At 35% of fiber volume fraction, the tensile strength was increased by 38.6% and 65% increased in tensile modulus. At lower volume fractions of banana fiber, the strength of the composite specimen was reduced when compared with the virgin resin. W.L. Lai et al. [9] investigated betel palm woven hybrid composite characteristics and testing features. It is found that the alkaline treatment of fibers effectively cleans the fiber surface and increases the fiber surface roughness. In general, mechanical properties of the woven composites made from alkali treated fibers were superior to the untreated fibers. Pothan et al. [10] investigated the influence of chemical modification on dynamic mechanical properties of banana fiber-reinforced polyester composites. Numbers of silane

coupling agents were used to modify the banana fibers. The damping peaks were found to be dependent on the nature of chemical treatment. Joseph et al. [11] studied the environmental durability of chemically modified banana-fiber-reinforced phenol formaldehyde (PF) composites. The authors observed that silane, NaOH, and acetylation treatments improved the resistance of the banana/PF composites on outdoor exposure and soil burial.

In recent years; the natural fiber woven fabrics are attractive as reinforcements since they provide excellent integrity and conformability for advanced structural applications. When comparing the woven fabrics composites with non-woven composites, they have excellent drape ability, reduced manufacturing costs and increased mechanical properties, especially the inter-laminar or interfacial strength. Several researchers has been investigated the mechanical properties of the woven fabrics polymer composite [12, 13].

In India, banana is abundantly cultivated. Banana fiber can be obtained easily from the plants which are rendered as waste after the fruits have ripened. So banana fiber can be explored as a potential reinforcement.

The objective of this paper is to study the effect of silane treatment on woven banana fabric on tensile, flexural strength and water absorption of WBF/UPR composite. FT-IR was utilized to characterize the chemically modified fibers.

2. Materials and Methods

2.1 Materials

Unsaturated polyester resin (UPR) resin (KPR- 6600), cobalt octoate as accelerator , methyl ethyl ketone peroxide (MEKP) as catalyst were provided by Kemrock Industries and Exports Ltd, Halol, Gujarat, India and banana woven fabrics (WBF) were obtained from Vedhanayaki fabs, Tamilnadu. Vinyl triethoxysilane was obtained from Sigma Aldrich Chemical Co. Ltd. Ethanol was supplied by Changshu yangyuan, China. Laboratory grade sodium hydroxide (NaOH) and glacial acetic acid were supplied by MERCK specialities private limited. The structure of silane coupling agent (vinyl triethoxysilane) is shown in Figure 1.

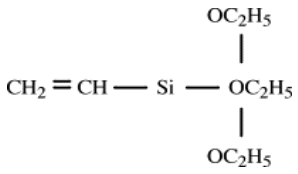


Figure 1. Structure of vinyl triethoxysilane

2.2 Silane treatment

Generally, the first step is the mercerization process (pre-treated process) for all of the fiber surface treatments. Mercerization causes the changes in the crystal structure of cellulose and then the different chemicals can be used on the fibers surface in order to improve the interfacial properties.

Fabric was pre-treated with 5% NaOH for about half an hour in order to activate the -OH groups of the cellulose and lignin in the fiber. Fabric was then washed many times in water and finally dried. 1% of the vinyl- triethoxysilane was mixed with an ethanol/water mixture in the ratio 6:4 mixed well and was allowed to stand for an hour. The pH of the solution was carefully controlled to bring about the complete hydrolysis of the silane by the addition of acetic acid. Fabric was dipped in the above solution and was allowed to remain there for 1 and 1/2 hours. The ethanol/water mixture was drained out and fabric was washed in water. It was then dried at room temperature for 2 hour, followed by drying in the oven at 70° C for 24 hours [14].

Silane used in this work has two functional groups, a hydrolysable group which can condense with the hydroxyls of the banana fibre and an organofunctional group capable of interacting with the matrix. The hydrolyzed silane can undergo the condensation and bond formation stage when influenced by acid or base-catalyzed mechanisms. Besides these reactions, the silanols can condense to give polysiloxanes. The silanol groups are chemically attached to the fibre through an ether linkage [15].

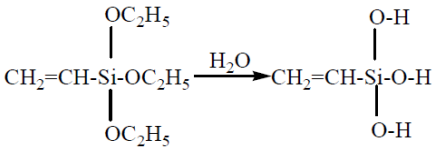


Figure 2. Hydrolysis of silane

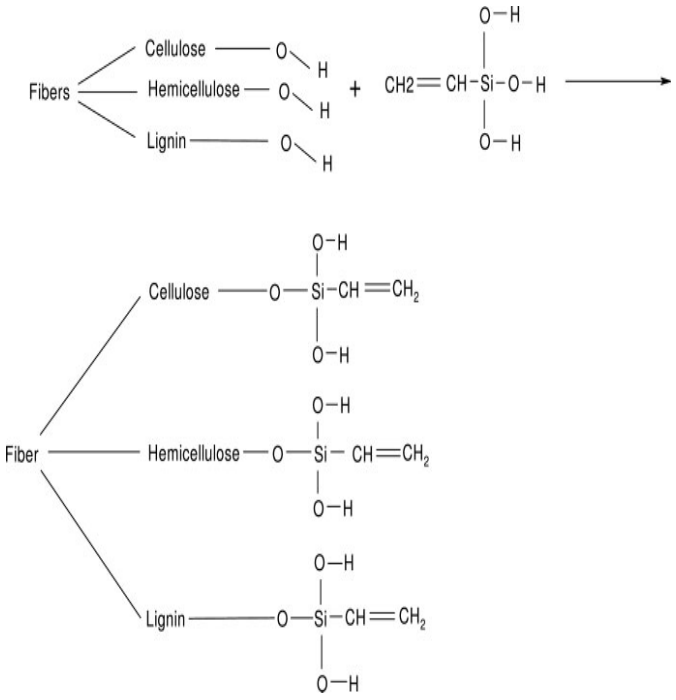


Figure 3. Hypothetical reaction of fibers and silane

2.3 Preparation of composites

Untreated and silane treated WBF/UPR composites were prepared by hand lay-up technique. Composite sheets were prepared by impregnating the WBF with the UPR to which 1% cobalt octoate and 1.5% methyl ethyl ketone peroxide (MEKP) were added. Air bubbles were removed carefully with roller. All composites contained 35% by weight fiber loading. The four layered composites were cured at room temperature until it was dry. After curing the composite, the specimens were cut for tests according to the ASTM standards.

2.4 Fourier Transform Infrared (FTIR) Spectroscopy

The IR spectra of untreated and silane treated fiber samples were recorded by using a FTIR spectrometer (Perkin Elmer). Each spectrum was obtained within the range:450-4000cm^{-1}.

2.5 Mechanical properties

The tensile test and flexural test were conducted according to ASTM standard testing methods D638 and D790, respectively. The tests were conducted on a INSTRON - Universal testing machine (Model-3382) at room temperature.

2.6 Water absorption

Water absorption test is carried out as per ASTM D-570. Prior to testing, the fibers were dried in an oven at 70ºC for 24 hours. The weights of dried samples were measured and the moisture absorption was calculated by the weight difference. After weighing on an analytical balance, the moisture absorption was calculated according to equation,

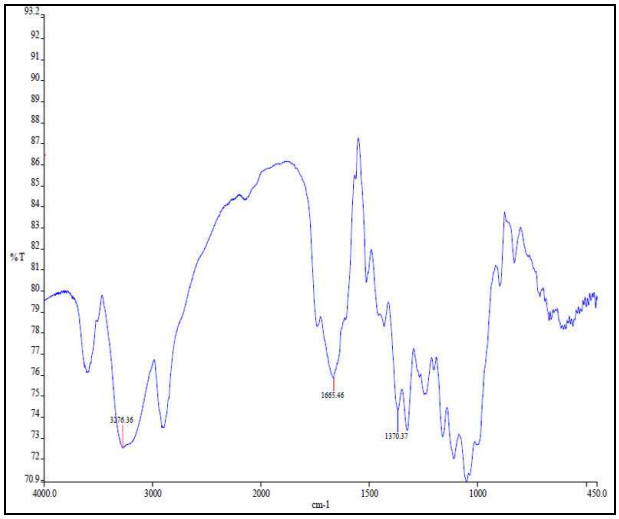
$$\text{Increase in weight (\%)} = \left(\frac{M_t - M_o}{M_o}\right) \times 100$$

Where: Mt = mass of the sample after conditioning (g) (wet weight), Mo= mass of the sample before conditioning (g) (dry weight).

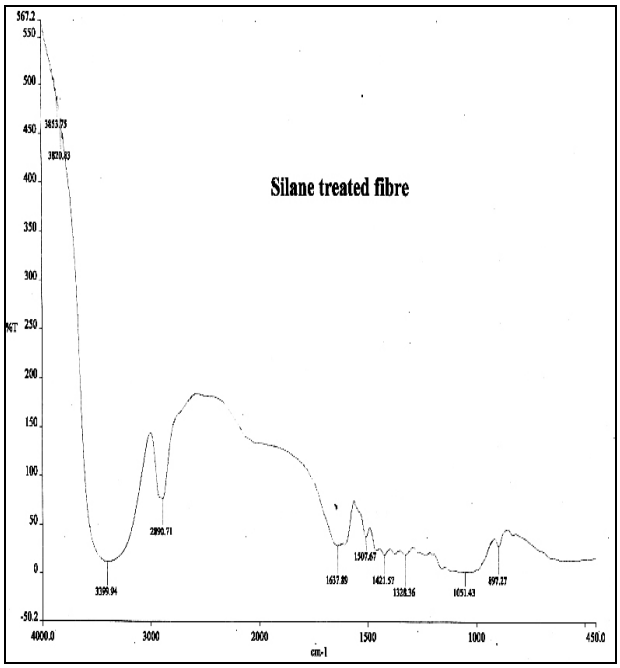
3. Results and Discussion

3.1 FTIR Spectroscopy

Figure 4 shows the FT-IR spectrum of untreated and silane treated banana fibers. The characteristics peaks obtained for the untreated fibers are as shown in figure. The band at 3276 cm^{-1} in untreated fiber is characteristics of the hydrogen bonded -OH stretching vibration. The peak at 1665 cm^{-1} is the characteristic band for carbonyls (C-0) stretching. The band near 1370 cm^{-1} is due to -C-0-C- bond in the cellulose chain. The band around 1051 cm^{-1} can be attributed to the asymmetric stretching of the -Si-O-Si and or to the -Si-O-C- bonds. The former bond is indicative of the polysiloxanes deposited on the fibre while the latter points to a condensation reaction between the silane coupling agent and the fibre. The presence of a few residual -Si-OH bonds is revealed by the band around 897 cm^{-1} [16].



(a)



(b)

Figure 4. FT-IR spectrum of (a) untreated and (b) silane treated banana fibers

3.2 Mechanical Properties

Figure 5 shows the tensile and flexural strength of WBF/UPR composite. Tensile strength is 39 MPa for the untreated composite, it is 45 MPa for the composites treated with Vinyl triethoxysilane. Flexural strength of silane treated & untreated WBF/UPR composite was 70 MPa and 58 MPa respectively. The tensile strength of the samples treated with the vinyl triethoxysilane, is found higher than the tensile strength of untreated samples. Earlier studies indicated that the acceptor number, which is indicative of the electron accepting ability, is found highest for fibres treated with the vinyl triethoxysilane [17]. The E_T (30) parameter which is indicative of the overall polarity is also found to be maximum for fibres treated with the silane. The reason can be attributed to the improved interactions between the organofunctional group and the unsaturated polyester matrix. The organofunctional group of the silanes in turns form-interpenetrating polymer networks, with the polyester [18]. The higher flexural strength was due to good bonding between fibre and matrix.

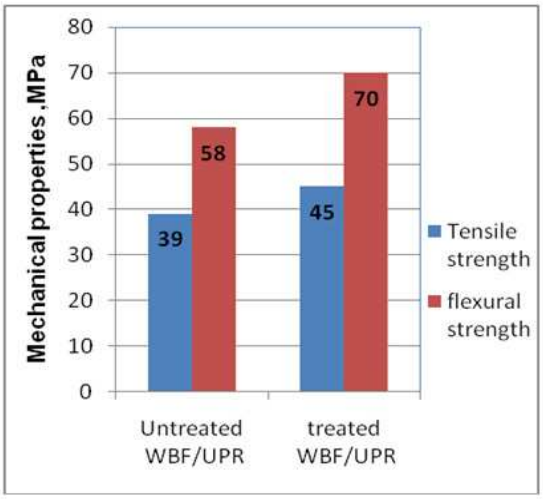


Figure 5. Tensile & Flexural Strength of untreated & treated WBF/UPR composite

3.3 Water absorption

Natural fibers are strongly hydrophilic materials with many hydroxyl groups (–OH) in the fibers structure and moisture absorption. Banana fiber is natural fibers; the hydrophilic nature of banana causes the water uptake by these lignocellulosic materials which due to the formation of hydrogen bonds between fiber and water molecules. It is well known that fiber absorbs water by forming hydrogen bonding between water on the all cell wall of the fiber [19]. With the presence of hydroxyl groups, banana fiber tends to show low moisture resistance. Untreated WBF/UPR composites showed 9.74 % moisture uptake and silane treated WBF/UPR composites showed 1.8% moisture uptake which shows that by using silane treatment there was reduction in the water absorption of the WBF/UPR composites as shown in Figure 6. It is believed that the by providing additional sites for mechanical interlocking, alkali treatment leads to improvement of interfacial bonding hence promoting resin/fiber interpenetration at the interface. This hydrophobic resin pick-up could also account for the reduction in water absorption. Silane treatment after mercerization reduced the water uptake by composites. Composites having mercerized fibers coupled with silane treatment exhibit better behavior, suggesting that changes in surface property have reduced the hydrophilic nature of the fibers. Fibers are modified in the molecular level due to chemical bonding between fiber and the silanes. Such linkages might have lead to better interfacial bondage, better adhesion and which has reduced the water absorption [20].

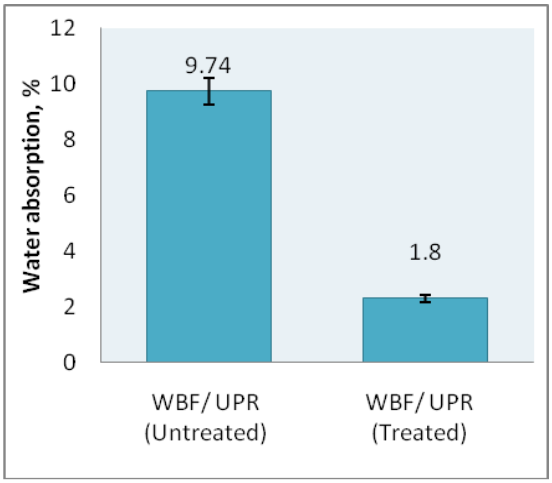


Figure 6. Water absorption of untreated & treated WBF/UPR composites

4. Conclusion

The mechanical properties, water absorption of untreated and silane treated WBF have been studied. The results obtained in this work show that the silane treated WBF composites have higher strength than that of the untreated WBF composites. Banana fiber is hydrophilic due to the presence of hydroxyl groups from cellulose and lignin. Chemical treatment can reduce the hydrophilicity of the fabric by treating these fibers with silane to decrease the hydroxyl groups in the fibers shown by FTIR. The Silane treatment has improved the mechanical properties (tensile & flexural strength) of WBF/UPR composite. Surface modifications of hydrophilic natural fibers have achieved some degree of success in making a superior interface between fiber and matrix and also improved in mechanical properties.

5. Acknowledgement

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