APPLICATION OF NON-WOVEN PREFORMS BASED ON NATURAL FIBRES AS REINFORCEMENT IN ECO-COMPOSITES

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ABSTRACT

Last decade, the interest in using natural fibres in eco-composites has grown because they are lightweight, non-toxic, non-abrasive during processing, low cost and easy to recycle. On the other hand, lack of good interfacial adhesion and poor resistance to moisture absorption make the use of natural fibre-based polymer composites less attractive. Chemical treatment of the fibres can stop the moisture absorption process, clean the fibre surface, chemically modify the surface or increase the surface roughness. Due to the chemical treatment, the cell wall hydroxyl groups are substitute rendering the natural fibre surface more hydrophobic and, thus more compatible to the polymer matrix.

This work compared the non-woven preforms based on natural fibres (flax and kenaf fibres), applied as reinforcement in eco-composites. Non-woven preforms have been modified by alkaline treatment, benzoylation and acetylation. Morphological and structural changes of the fibres resulted from the performed modifications were analyzed by FTIR, TGA and SEM. The natural fibre non-woven preforms were processed by compression moulding and the obtained eco-composites were analyzed by standard methods such as mechanical test, TGA and SEM.

1. INTRODUCTION

Last decade, the interest in using natural fibres of different preforms and fabrics for eco-composites has grown because they are lightweight, non-toxic, non-abrasive during processing, low cost and easy to recycle. Natural fibers reinforced materials offer target environmental advantages such as reduced dependence on non-renewable energy/material sources, lower pollutant and greenhouse emissions. Natural lignocellulosic fibers (flax, jute, hemp, *etc.*) represent an environmentally friendly alternatives to conventional reinforcing fibers (glass, carbon). Advantages of natural fibers over traditional ones are: low cost, high toughness, low density, good specific strength properties, reduced tool wear (nonabrasive to processing equipment), enhanced energy recovery, CO_2 neutral when burned, biodegradability. Due to their hollow and cellular nature, natural fibers preform act as acoustic and thermal insulators, and exhibit reduced bulk density. Depending on their performance when they are included in the polymer matrix, lignocellulosic fibers can be classified in three categories: 1) wood flour particulate which increase the tensile and flexural modulus of the composites, 2) fibers of higher aspect ratio that contribute to improve the composites modulus and strength when suitable additives are used to regulate the stress transfer between the matrix and the fibers, 3) long natural fibers with the highest efficiency amongst the lignocellulosic reinforcements. The most efficient natural fibers have been considered those that have a high cellulose content coupled with a low microfibril angle, resulting in high filament mechanical properties.

New and stronger environmental policies have forced some industries such as automotive and construction industry to look for new eco-materials that will be able to substitute traditional composites reinforced with glass or carbon fibers [1]. For automakers, it becomes very important to improve recyclability of newly produced vehicles. The European Commission recently proposed a European Guideline 2000/53/EG that sets a goal of improving automotive recyclability, 85 % of a vehicle by weight being recyclable by 2005 and 95% by 2015 [2]. Muller & Stryjewski have studied application of non-woven composite fabrics in automotive interior components. They have compared carded and needlepunched nonwoven fabrics of 750 g/m2 produced from 50/50 Kenaf/PP, jute/PP and Flax/PP [3].

This work compared the non-woven preforms based on natural fibres, flax and kenaf fibres, applied as reinforcement in eco-composites.

2. EXPERIMENTS

2.1. Modification of natural fibers

Flax and kenaf fibers were kindly supplied by KEFI-Italy. Surface modification was carried out as follows: (a) ***dewaxing:*** the fibers were treated with 1:2 mixture of ethanol/benzene for 72 h at 50 °C, followed by washing with distilled water and air drying to get defatted fibers [3]; (b) ***vinyl monomer grafting***: acrylonitrile (ACN) graft copolymerization onto dewatted fibers was carried out using using 0,01 M Ce^{4+}/ 0.1*M* HNO_3 as initiator at temperaure of 50^{o}C [3]; (c) ***alkali treatment***: the defatted fibers were treated with 10% NaOH solution for 1 h at 30 °C [3]; (d) ***acetylation:*** dewatted fibers were placed in 100 ml flask and covered with appropriate amount of acetic anhydride for 0.5 h at 20 °C, followed by Soxhlet extraction and drying.

2.2. Fiber characterization

FTIR measurements were carried out by using ATR technique (Perkin Elmer-2000 FTIR Spectrometer). Samples were dried for 24 hours in vacuum before analysis.

The morphology of chemically treated and dried (12 hours in vacuum) kenaf fibers was examined by JEOL scanning electron microscope, model JSM-T20 (U_w = 20 kV).

Thermogravimetrtic analysis (TGA) was performed at heating rate of 20 and 5 ^{o}C/min (under nitrogen), using Perkin Elmer DIAMOND system.

2.3. Composite characterization

Eco-composites based on Polylactide (PLA) matrix reinforced with flax and kenaf nonwoven performs (20% wt. fiber content) have been prepared by compression moulding at 170 ^{o}C under the pressure of 50 bars.

The flexural strength and the flexural modulus were measured in three-points bending mode using an Instron machine (model 5564), at a cross-head speed of 1 mm/min and at room temperature. Test specimens were 3.5 mm thick, 6.0 mm wide and 60 mm long. The test span was 48.0 mm. For each sample 10 specimens were tested and the average values of the flexural strength and modulus were calculated.

Thermogravimetrtic analysis (TGA) was performed in the range of 25 to 800 ^{o}C, at heating rate of 20 (under nitrogen), using Perkin Elmer DIAMOND system.

3. EXPERIMENTAL RESULTS

3.1. Characterization of the natural fiber performs

The effects of the surface modifications of the natural fibre performs of flax and kenaf fibres have been followed by several techniques. Using the FTIR spectroscopy, qualitatively have been confirmed the chemical changes induced by different surface treatment. Characteristic FTIR spectra are presented on Fig. 1 for kenaf fibres, and in Fig.2-for flax fibres. It can be noticed that the most significant changes have been induced by acetylation and alkalization of kenaf fibres which resulted in appearance or an increment of the absorbance in the region 1200-1500 cm^{-1} (Fig. 1). The removal of hydroxyl groups as a result of esterification (acetylation) is evidenced by disappearance of the strong absorption between 3200-3600 cm^{-1} caused by the OH groups of the fiber constituents. In the spectrum of alkali treated kenaf fibers, disappearance of the band at 1740 cm^{-1} clearly indicates changes in the fiber surface chemical composition. For flax treated fibres (Fig. 2), changes were seen in the region of 2920 cm^{-1} (C-H stretching in cellulose and hemicellulose): the band intensity decreased, indicating that part of the hemicellulose was removed.

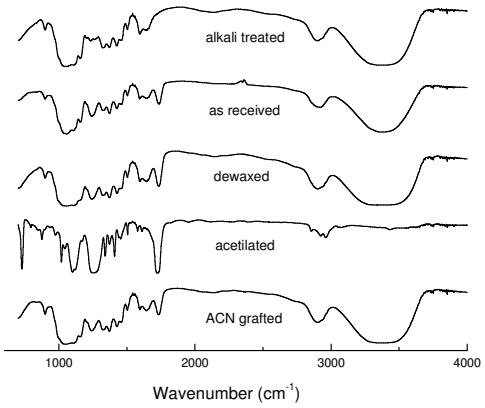
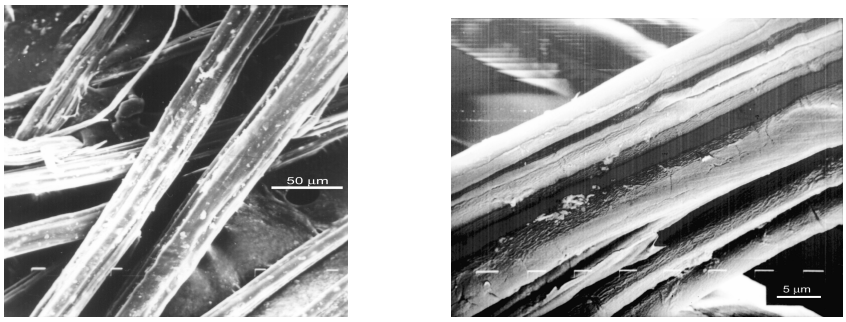


Fig. 1. FTIR spectra for different treated kenaf fibres

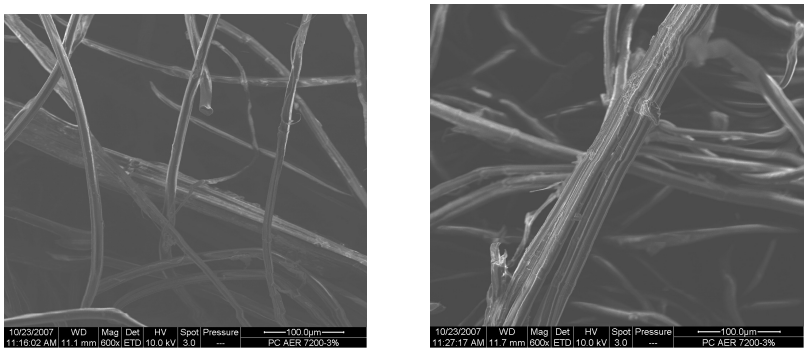
Fig. 2. FTIR spectra for flax fibres treated with different alkali concentration

Due to the chemical treatments, overall morphology of the flax and kenaf fibers has been changed. Characteristic SEM images of alkali treated flax and kenaf fibers are shown in fig. 3 (kenaf fib.) and 4 (flax fib.). The untreated fibers represent the bundles with relatively smooth surface (fig. 3a and fig. 4a), although small particles attached to the surface are also seen. The alkali treated fibers have a rough surface topography with significant defibrillization of individual fibers (fig. 3b and fig. 4b).



a) Kenaf-untreated (x200) b) Kenaf-alkali treated (x500)

Fig. 3 SEM microphotographs of alkali treated kenaf fibers



a) flax-untreated (x600) b) flax – alkali treated (x600)

Fig. 4. ESEM microphotographs of alkali treated flax fibers

Characteristic TGA thermograms for different treated flax and kenaf nonwoven performs are presented in Table 1. Comparison of the decomposition temperatures of flax and kenaf nonwoven performs has shown that higher thermal stability (about 70 ^{o}C) exhibited flax nonwoven performs probably as a result of higher crystallinity as well as higher cellulose and hemicellulose content.

Table 1. Decomposition temperature at different weight loss levels of treated flax and kenaf fibers

Differently treated fibers	T_d [^{o}C] flax fib. (~ 50%)	kenaf fib. (~50 %)	T_d [^{o}C] flax fib. (~ 90%)	kenaf fib. (~ 90%)
As received	448	384	492	415
Alkali treated	450	360	494	416

3.2. Mechanical behavior of the eco-composites

Mechanical properties of the eco-composites reinforced with flax and kenaf nonwoven preforms have been shown in Table 2. Evidently, flax and kenaf nonwoven performs increased the mechanical properties of the PLA neat polymer. Higher flexural modulus

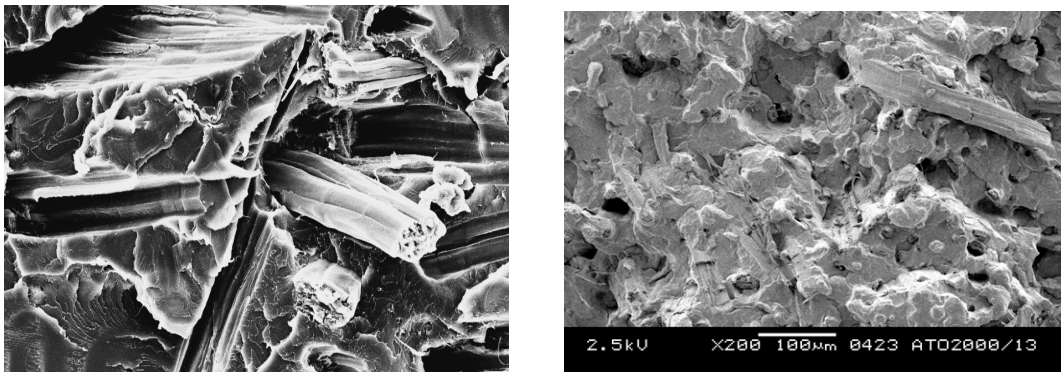
was obtained for the composites reinforced with kenaf fibres, while higher flexural strength was measured for PLA/flax eco-composites.

Table 2. Flexural data for PLA based eco-composites reinforced with flax and kenaf nonwoven performs

Sample	Flexural modulus [MPa]	Flexural strength [MPa]
PLA neat	3550 ± 50	30.9 ± 0.2
PLA/Kenaf (80/20 %wt)	4630 ± 40	32.7 ± 0.4
PLA/flax (80/20 %wt)	4400 ± 40	36.6 ± 1.8

3.3. Fracture morphology

Some of the SEM microphotographs with the characteristic morphology obtained at the fracture place during the flexural test of the studied eco-composites are presented on Fig. 5. Fig. 5.a. represents the fracture morphology of the PLA/Kenaf eco-composite, while the Fig. 5.b. represents the PLA/flas based eco-composites. For both composites some voids have been registered.



a) PLA/Kenaf (80/20% wt) (x500) b) PLA/flax (80/20 % wt.) (x200)

Fig. 5. SEM microphotgraphs of the PLA eco-composites reinforced with nonwoven kenaf and flax preforms
a) PLA/Kenaf (80/20% wt) (x500); b) PLA/flax (80/20 % wt.) (x200)

4. CONCLUSIONS

Two types of natural fibre nonwoven performs have been alkali treated and used as reinforcement for PLA based eco-composites.

Flax and kenaf nonwooven preforms have been treated by different surface treatments. Using the FTIR spectroscopy, qualitatively have been confirmed the chemical changes induced by different surface treatment. Comparison of the decomposition temperatures of alkali treated flax and kenaf nonwoven performs has shown that higher thermal stability exhibited flax nonwoven performs.

Flexural test measurements have shown higher flexural modulus for PLA composites reinforced with kenaf fibres, while higher flexural strength was measured for PLA/flax eco-composites.

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