Reliability Improvement of Hemp Based Bio-composite by Surface Modification

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Abstract: The influence of the surface treatments on the performance of the hemp/PP (polypropylene) composite was investigated. The composites were prepared from the fiber modified by the alkalis and the oil under various conditions. The mechanical properties of the composites were measured using the tensile test, and the service time of the composite was assessed under accelerated condition by the stepped isothermal method. The alkaline treatment removed the lignin successfully and resulted in better fibrillation. The oil treatment improved the mechanical properties of the composites and extended the service life time of the composites.

Keywords: Composites, Biofibers, Modification

Introduction

Synthetic fiber extended its application areas from apparel to technical textiles such as filters, geo-textiles and reinforcement for composites. The composites replaced the conventional material rapidly [1-3]. Especially, the composites reinforced by synthetic, glass, and carbon fibers are wildly used in vehicle and aircraft industries due to their lightweight and excellent performances. However, the synthetic fibers for the reinforcement used have significant drawbacks such as non-biodegradability, petroleum dependence and huge amounts of carbon dioxide release during manufacturing processes. The production and the consumption of the fibers are considered as the major cause of global warming and exhaustion of petroleum. To solve those problems, many researchers have tried to replace synthetic and glass fibers with natural fibers. Comparing with other natural fibers, hemp is considered as one of the best potential candidates due to its high modulus and strength.

Hemp fiber reinforced composites has drawn a great of attractions from researchers due to its superior properties. Currently, there were many reports for the hemp composite with various preparation conditions such as the matrix type [4] and the effect of water absorption [5]. Particularly, the mechanical properties of hemp composites were influenced by hemp fiber length with surface treatment [6] and hemp content [10]. Notwithstanding many benefits of hems, the mechanical properties of the hemp composites are not acceptable for many application areas because of the poor interfacial adhesion between the hemp fiber and the matrix. In order to improve the adhesion of hemp fiber to polymeric matrix, the several researches on chemical modification were carried out [4-11]. Among them, the treatment using vegetable oils [12] is a one of the most efficient methods, and engaged attention to improve the mechanical properties of hemp composite.

When the composites are used in application areas, the service life of the composite is very important and needs to be estimated. The concept of reliability allows one to take into account the failure modes and mechanisms, and the estimated life times of the products [13,14]. As the longer service time and the better performance are required, the understanding of reliability becomes more critical in various industries such as electric, electron, part and material industries [15-18]. Although, comparing to other industrial materials, the reliability studies of fibers and textiles are few, it becomes more important as they reinforce the composites used in auto-vehicles, aircrafts and buildings. The reliability assessment of fibers and textiles are usually based on polymer degradation and failures.

In this study, hemp fiber reinforced composites were successfully prepared using polypropylene under various conditions. The effects of the fiber contents and the fiber surface modification on the properties were intensively studied especially focusing on the mechanical properties and the life time of the composite. The fiber surface was modified using alkaline and vegetable treatments. The experimental results revealed that the composite made of the treated fibers showed better mechanical performance and a longer estimated life time.

Experimental

Materials and Composite Preparation

The hemp (HempLee Korea Co.) for the reinforcement was treated by alkaline solutions (NaOH/Na\textsubscript{2}SO\textsubscript{3} aqueous solution, 5 wt/2 wt %) with different temperatures (50, 80, 100, 120, 150 and 180 °C) and then treated by vegetable oils (soybean and corn oils, Aldrich Co.). In each oil treatment, the hemp fibers (3 g) were immersed into the oil dispersed acetone (1, 2 and 3 %) and stirred for 3 hours. After dried in an oven, the fibers were rinsed with acetone.
After each treatment, the fiber was cut into 2 mm length and then mixed with polypropylene (PP, Aldrich). The fiber content in the mixture was fixed as 10 and 20 wt%. The mixture was heated to melt the PP using a hot press for 4 minutes at 190°C and pressed under 60 kg/m² for 1 minute. The sample preparation conditions were summarized in Table 1.

Characterization
The chemical structure change of the hemp by the treatments was determined by FT-IR (JASCO, FT/IR-300E). The thermal properties of the fiber were observed with TGA (TA instrument, TGA@500) in nitrogen atmosphere. The mechanical properties of the composites were measured using a universal tensile machine (Instron5584). The fiber surface was observed by a scanning electron microscope (JEOL, JSM-6360A).

Accelerated Life Test
In this study, the primary failure mode of the composites was considered as creep deformation. In order to estimate the service life of the composite, we carried out an accelerated life test according to SIM (Stepped Isothermal Method). Using the test, the initial strain value of accelerated creep curve was determined. In the test, the creep temperature increased step-wisely from 20 to 78°C with 5 steps under load of 35N. The creep of the composite was measured at each step after a duration of 200 minutes. From the test, we obtained the creep strain master curve by the procedure illustrated in Figure 1. After obtaining a master curve for creep, the mean times to failure (MTTF) for 1, 1.5 and 2% of creep strain were calculated based on the curve.

Results and Discussion

Fiber Surface Observation
Figure 2 shows the SEM images of the hemp fiber treated by alkaline solutions under various temperatures. Comparing with the untreated fiber, it was found that the treated fiber was more fibrillated and had less fiber diameter. The alkaline treatment removed the non-cellulose parts such as lignin and hemicelluloses from the hemp fiber and resulted in better fibrillation and less diameter. The fiber diameter was also decreased with the increase of the treatment temperature. It shows that the non-cellulose region was effectively removed under high temperature.

Chemical Structure
Figure 3 shows the FT-IR Spectra of the hemp fiber treated by the alkaline solution. As similar to Dankovich’s study [6], the peak at 1720 cm⁻¹ became smaller and the

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![Figure 1](image1.png)

![Figure 2](image2.png)