ASSESSMENT OF TWO COMPATIBILIZATION TECHNIQUES FOR *GUADUA ANGUSTIFOLIA* BAMBOO FIBERS AS REINFORCEMENT OF POLYMERIC MATRICES

EVALUACIÓN DE DOS TÉCNICAS DE COMPATIBILIZACIÓN PARA LAS FIBRAS DE BAMBÚ *GUADUA ANGUSTIFOLIA* COMO REFUERZO DE MATRICES POLIMÉRICAS

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Abstract

Natural fibers have become a valuable resource in composite industry; however, its use is restricted due to the weak compatibility with common matrices employed. Low compatibility bring as consequence low mechanical strength of composite material. To avoiding this, it is necessary to treat the reinforcement material or matrix before the composite manufacturing. This paper presents the results obtained during the study of using two different compatibilization techniques for natural fibers, which will be used as reinforcement of polymeric matrices. The studied techniques are: sodium hydroxide (NaOH) as coupling agent and a dry etching plasma (physical sputtering). Natural fibers employed were obtained from *Guadua angustifolia* bamboo culms. The manufacturing of composite material was made using a manual moulding technique, with polyester as matrix. The objective was studying the influence of the applied compatibilization techniques on compression strength of guadua-polyester composites. The results revealed that treating *Guadua angustifolia* bamboo fibers with sodium hydroxide increase the compression strength of the composite material.

Keywords: *Guadua angustifolia* bamboo fiber; sodium hydroxide; dry etching plasma; guadua-polyester composites; compression strength

Resumen

Las fibras naturales se han convertido en un recurso importante para la industria de los compuestos; sin embargo, su uso ha sido restringido debido a la baja compatibilidad con las matrices comúnmente empleadas. La baja compatibilidad trae como consecuencia baja resistencia mecánica del material compuesto. Para evitar esto, es necesario tratar el material de refuerzo o la matriz antes de la fabricación del compuesto. Este trabajo presenta los resultados obtenidos durante un estudio enfocado a investigar dos técnicas de compatibilización para fibras naturales, las cuales serán usadas como refuerzo de matrices poliméricas. Las técnicas usadas fueron: hidróxido de sodio (NaOH) como agente de acoplamiento y plasma de grabado en seco (pulverización catódica). Las fibras natrales empleadas fueron obtenidas de culmos de bambú Guadua angustifolia. La fabricación del material compuesto fue realizada por moldeo manual, usando resina de poliéster como matriz. El objetivo era estudiar la influencia de la técnica de compatibilización empleada en la resistencia a compresión de compuestos poliéster-guadua. Los resultados muestran que tratar fibras de bambú Guadua angustifolia con hidróxido de sodio incrementa la resistencia a compresión del material compuesto.

***Palabras clave**: Fibra de bambú Guadua angustifolia; hidróxido de sodio; plasma de grabado en seco; compuestos poliéster-guadua; resistencia a compresión.*

1. INTRODUCTION

The use of natural fibers as reinforcement of polymeric matrices has increase during the last two decades [1]–[5], due the interest in composite industry for making products with lower costs than composites reinforced with synthetic fibers and for the benefits that using natural resources bring to the environment.

The mechanical properties of composite materials depends on the mechanical properties of its constituents (fibers and matrix) and the properties of the interfacial region (which is the region between fibers and matrix material). The properties of the interfacial region are consequence of all possible physico-chemical interactions between composite constituents and are directly responsible of the stress transfer process from the matrix to the fibers.

The main problem of using natural fibers as reinforcement of polymeric matrices is the low chemical compatibility between composite phases, due to the hydrophilic behavior of fibers and hydrophobic behavior of polymers. Low chemical compatibility may bring an inadequate mechanical behavior of the composite material due to a low adherence between composite phases.

In literature there two main procedures in order to overcome the limitations of using natural fibers as reinforcement material of polymers. The first procedure is focused on the modification of physico-chemical properties of matrices and the second on the modification of the physico-chemical properties of fibers. For industrial applications, the second procedure is commonly used. The modification of physico-chemical properties of fibers can be achieve by using coupling agents, making a graft polymerization of monomers compatible with the polymer matrix or using plasma treatments.

The main objective of using coupling agents is that they react with the hydroxyl groups that are present at the hemicellulose, lignin and amorphous cellulose region of natural fibers, which confers its hydrophilic behavior. Also, this treatments expose the cellulose structure to react with the binding materials [6]–[8]. The main disadvantage of using this kind of treatments is that they could react also with the hydroxyl groups on the crystalline cellulose region, producing a reconfiguration of the fiber's structure that diminish its mechanical properties [2], [6], [9]. Using this technique, the compatibilization between composite phases is made following a purely chemical approach.

Another innovative alternative for changing the physico-chemical properties of fibers is by using plasma treatments. From a general point of view, there are three main purposes of applying plasma treatments in material science: functionalization of surfaces, deposition of thin films, and etching. Etching processes are focused on removing some material from the surface. The removal can be achieved using a physical sputtering procedure, in which the material is removed by purely physical processes, due to the ion bombardment of species present in plasma. The main advantage of using plasma treatments is that the alterations do not affect the bulk properties of the material. Using this technique, the compatibilization between composite phases is made following a purely physical approach, by the increasing of the mechanical grip between the fibers and the polymer.

This paper presents the results of a research aimed to use two different compatibilization techniques between polymers and natural fibers, focused on the modification of the physico-chemical properties of fibers. The used techniques are a common coupling agent as sodium hydroxide and a dry etching plasma (physical sputtering). The natural fibers were extracted from *Guadua angustifolia* bamboo culms. In order to establish the influence of the applied techniques on the mechanical behavior of a composite material, were fabricated samples using polyester as matrix, reinforced with non-treated fibers and treated using both techniques. The composite material was fabricated using the manual moulding technique. The samples were tested under compression, following the international standard ASTM D645.

2. EXPERIMENTAL DETAILS

2.1 Extraction of *Guadua angustifolia* bamboo fibers

Guadua angustifolia bamboo fibers (guadua fibers) were obtained following a procedure similar to describes on [10]. Initially, the *Guadua angustifolia* culm, between 3 and 6 years of age, was divided in segments of approximately 60cm of length. These segments were divided in longitudinal strips with cross-sectional dimensions of 0.025m x t, where t is the wall thickness of the wall. For removal the protuberance at nodes and to eliminate the external layer, each strip was polished. In order to soften the material after extraction process, polished strips were immersed during 3 hours in a sodium hydroxide solution, with a concentration of 2.5% previously heated at 80°C and the temperature was maintained during the immersion time. After immersion time, the strips were washed deeply using tap water. To obtaining the fibers, was used a mechanical process using the machine describes in [10]. All fibers were carefully washed using tap water, and dried at laboratory temperature. For this research, only the bottom part of guadua culms were used, and the average length of obtained fibers using this procedure was 10 cm.

2.2 Compatibilization treatments

Guadua fibers were treated in order to increase the compatibility with polyester matrix. The compatibilization was made using a coupling agent and dry etching plasma, separately.

For coupling agent treatments, guadua fibers were immersed in sodium hydroxide solutions, using different concentrations and different immersion times. The used concentrations were 1% and 10%, and the immersion times were 30min and 180min. After treatment, the fibers were carefully washed using tap water.

The variable for dry etching plasma was the treatment time. Guadua fibers were exposed during 100s and 1000s to ion bombardment. These treatments were made using a DC sputtering (etching) system and employing Argon (Ar) gas to plasma generation. All treatments were performed using an average current of 30 ± 3 mA and a working pressure of 10^{-2} kPa.

2.3 Composite preparation

The samples of guadua-polyester composite were fabricated using a manual moulding technique. For this, was used a polyester resin with commercial reference 555 and peroxicol as hardener, added at 2%. For the fabrication were used cylindrical molds with average dimensions of 25mm x 60mm (diameter x heigth). All specimens were fabricated using a weight fiber fraction of 1% (weight of fibers/weight of composite). Long treated and non-treated fibers were placed into the molds, using a random distribution; after this, the resin (with hardener) was added. After the resin was hardened, the specimens were demolded and the top surface was polished in order to get an homogenous plane. The final average dimensions for the composite samples were 25mm x 54mm (diameter x heigth). For each compatibilization treatment were fabricated three samples for the mechanical tests. Figure 1 shows schematicaly the procedure used for composite fabrication and Figure 2 an example of a guadua-polyester sample.

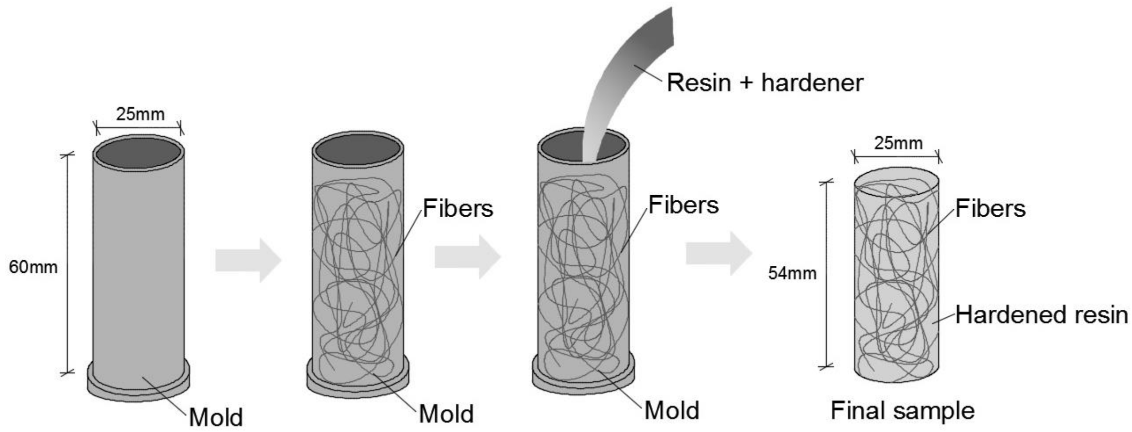

Figure 1: Schematically representation of guadua-polyester composite fabrication

Figure 2: Guadua-polyester sample for compression tests

2.4 Compression tests of composite material

Compression tests were performed following the guidelines of international standard ASTM D645. The mechanical tests were made in a Shimadzu universal machine with maximum capacity of 300kN, using a loading rate of 1.3mm/min. In order to guarantee an axial load during the mechanical tests all samples were placed over an external joint, as shows Figure 3.

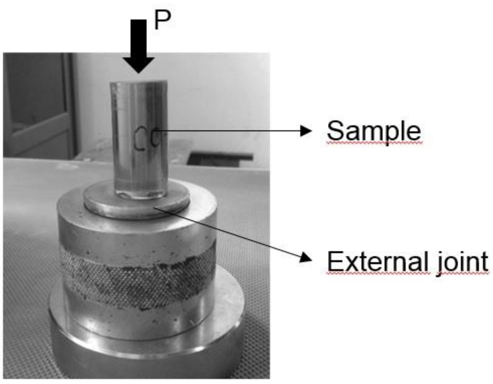

Figure 3: External joint for mechanical test

For each sample was calculated the compression strength (σ_c) using equation (1), where P_{max} is the maximum load during the test and A the cross-sectional area.

$$s_c = \frac{P_{max}}{A} \quad (1)$$

3. RESULTS AND DISCUSSION

Figure 4 shows the results in terms of compression strength for each applied treatment. The nomenclature used to identify each sample type was: W correspond to samples reinforced using fibers without treatment; P identifies the samples using fibers treated with plasma and 100 and 1000 correspond to exposure time; H was used for samples reinforced with fibers treated using sodium hydroxide, 1 or 10 identify the solution concentration and 30 or 180 the immersion time.

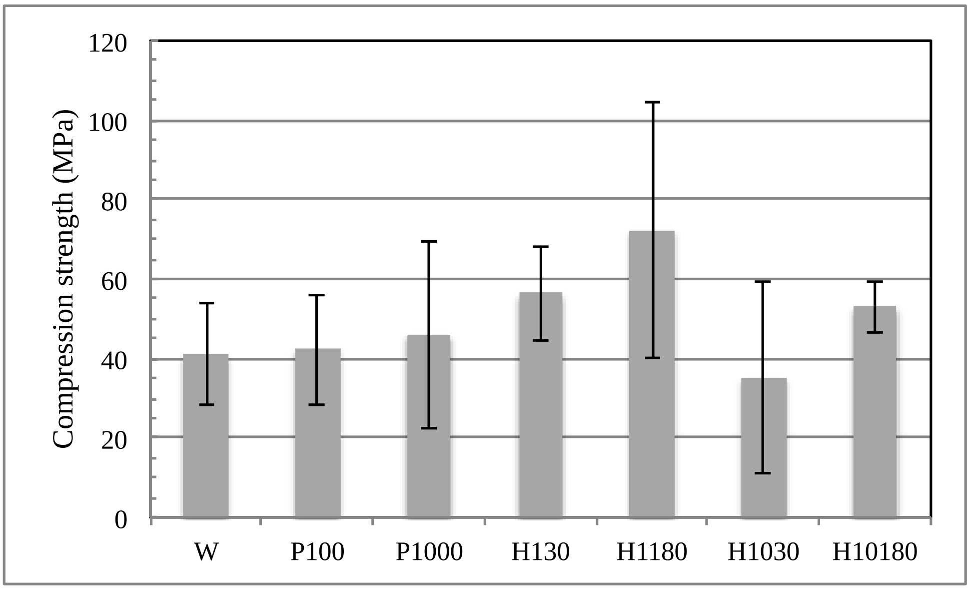

Figure 4: Experimental results for each compatibilization treatment

The results show that plasma treatment does not change the mechanical response of composite material. Instead, treating fibers with sodium hydroxide increase the compression strength of guadua-polyester composite; the highest strength value was obtained for samples reinforced with fibers treated with 1% of solution concentration during 180min. This increment could be consequence of an increment in the adherence between composite phases. The value obtained for samples H1030 could be affected for fabrication deffects, that generate failure planes.

Similar results were obtained by Cuellar & Muñoz [11]; they prepared guadua-polyester composites employing a similar technique used on this research, an samples were reinforced at 10%. The compatibilization was made using sodium hydroxide solutions at 5% and 10% of concentration during 30min. The results of compression tests reveal an increment on the mechanical strength of the samples reinforced with treated guadua fibers. The highest compression strength was obtained for the samples fabricated with fibers treated with 10% of concentration.

4. CONCLUSIONS

It can be concluded that the modification of physico-chemical properties of guadua fibers using a coupling agent as sodium hydroxide increase the compression strength of guadua-polyester composites. The maximum value of compression strength was obtained for composites reinforced with guadua fibers treated using a concentration of 1% during 180min. This increment could be attributed to an increment on the adherence between composite phases, due to the compatibilization of used fibers and polyester polymer.

Even the results of composites reinforced with guadua fibers treated with plasma do not present significant differences from the samples fabricated using fibers without treatment, this is an innovative technique that has to be explore in order to increase the adherence between composite phases.

On the next stage of the research, fibers treated using the same compatibilization techniques will be used to fabricate and test guadua-polyester samples in tension and bending.

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