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Elaboration of the cabuya fiber in flat fabric as reinforcement matrix for the construction of a rear-view mirror

Elaboración de la fibra de cabuya en tejido plano como matriz de refuerzo para la construcción de un retrovisor

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Abstract

Natural fibers are becoming an efficient alternative for industrial applications. This is due to its easy accessibility in the market and for being a renewable raw material. The present work seeks to use the cabuya as reinforcement material with polyester matrix for automotive applications with low cost and weight. This is the case of the rearview mirrors of a vehicle, for which a base mold was manufactured. The applying and molding of the rearview mirror will be carried out on the mold, using cabuya fiber and a polyester resin. The mixtures of cobalt octoate and methyl-ethyl-ketone peroxide (MEKP) with the natural fiber significantly reduce the weight; the manufacturing cost is reduced by approximately 40% due to the easiness to handle this fiber and to obtain this material. The use of the cabuya is recommended for automotive applications (rearview mirror), as it presents a considerable reduction in its weight and relatively low cost compared to the original component.

Keywords: Applications, natural fiber, extraction, molding, process.

Resumen

Las fibras naturales se han convirtiendo en una excelente alternativa para usos industriales. Esto se debe a su fácil accesibilidad en el mercado y por ser una materia prima renovable. El presente trabajo busca usar la cabuya como material de refuerzo con matriz poliéster para aplicaciones automotrices con bajo costo y peso. Este es el caso de los retrovisores de un vehículo, para el cual se fabricó un molde base. Sobre el molde se realizará el aplicado y moldeado del retrovisor utilizando la fibra de cabuya y una resina poliéster. Las mezclas de octoato de cobalto y peróxido de metil-etilcetona (MEKP) con la fibra natural reducen considerablemente el peso; el costo de manufactura se ve reducido aproximadamente en un 40 % debido a la facilidad de manejo de la fibra y la adquisición de este material. Se recomienda la utilización de la cabuya para aplicaciones automotrices (espejo retrovisor) ya que presenta una reducción considerable en su peso y costo relativamente bajo en comparación con el componente original.

Palabras clave: aplicaciones, fibra natural, extracción, moldeado, proceso.

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1. Introduction

Natural fibers are one-dimensional, long and thin structures. They bend easily, and their main purpose is the manufacture of fabrics. They are classified based on their origin, vegetal, animal or mineral. Likewise, fibers of vegetal origin are classified according to the part of the plant from which they are extracted [1], which enables obtaining a better nomenclature of the fibers produced in new research works.

The cabuya is a plant very common in the central region of Ecuador, where it is used by the farmers to feed the beef cattle. The fiber is obtained through a process which consists of different stages: removal of stalks, crushing, cooking, drying and combing.

In Ecuador, the development of composite materials is at the initial stages, and thus the use of natural fibers is still limited. In general, the extraction of vegetal fibers is carried out manually, but this may change taking into account the great potential offered by the country. It is important to know the production of domestic natural fibers [2].

On the other hand, the need for materials more environmentally friendly has boosted the study of natural polymers for their use in disposable applications, with the purpose of having a material available in nature and also biodegradable [3].

These composite materials represent an important alternative for replacing the reinforced composites based on metal, aluminum, chromium, tungsten, etc.; in many opportunities their properties are comparable or even superior.

Reducing the vehicle weight has been considered as one of the more important solutions to improve fuel saving, reduce weight-power ratio and end up having little or no polluting emissions. It is believed that the weight of the vehicle body can be reduced with the use of multiple materials without cost increase [4].

From the wide variety of composite materials available in the market, they are described as constituted by organic matrices (epoxy, vinylester, polyester) and high resistance fibers (glass, carbon, natural fibers, etc.), considering them as the most developed and the most often used at an industrial level [5].

With respect to the fibers, they are polycrystalline and amorphous materials, with small diameters and great length. In general, the fiber materials are polymers or ceramics (for example, aramids, glass, carbon, boron, aluminum oxide and silicon carbide). There is also the use of natural fibers such as abaca, cabuya and coconut, incorporated as reinforcement elements in a polymeric matrix. This type of materials offer many advantages, among which it can be remarked the reduction of the manufacturing cost and the smaller environmental impact [6].

Traditionally, the weight of the vehicles that take part in automobile competitions is considerably low, as it is the case of the Formula 1, enabling them to have a great performance, because they use lighter materials in the manufacturing of its components, and with characteristics similar to the originals.

According to the Ministry for Agriculture, Stockbreeding, Aquaculture and Fisheries (Ministerio de Agricultura, Ganadería, Acuacultura y Pesca, MAGAP) approximately 5400 tons of cabuya fiber were produced in Ecuador (2008). The Ecuadorian industries started to conduct tests to determine the resistance of this fiber [8], and thus its possible applications and development of new biodegradable composite materials.

The objective of using natural fibers in the manufacturing of a rearview mirror is facilitating that this element can be recycled, contributing to reduce the environmental impact caused by the automotive industry due to the use of different materials in the production of vehicles, as it is the case of plastics, and at the same time reduce the mass of its components [7, 8].

It is expected to obtain a lighter rearview mirror, with a considerable resistance to deformations due to impacts, as well as a considerable reduction of its manufacturing cost, taking into account a sustainability criterion in each production process; in addition, the possibility of introducing the cabuya fiber in the automotive industry of the country, enabling the development of new applications [9–11].

2. Materials and methods

2.1. Extraction of the cabuya fiber

It is necessary a correct selection of the cabuya plant to obtain stalks of greater size which, in turn, enable obtaining more fibers with less plants, thus improving the production efficiency. The approximate growth period is 5 years before removing the stalks, using a steel bar with sharp tip.

The following steps should be executed to extract the stalk:

1. Cut with a machete the stalk closer to the ground. 2. Chop the plant with the help of the bar in the place of the stalk that was cut (Figure 1), until reaching the center; once this is achieved a perpendicular force must be applied on the bar so that the plant opens (i.e., it is lifted), and all the stalks are freed. 3. Remove with the machete the thorns in each stalk. 4. Take the tip of the stalk with the hand and pull it performing a twisting motion until detaching it from its center. 5. Repeat step 4 with all the stalks. 6. Once all the stalks have been extracted, move them to the fiber extraction area.

Es necesaria una correcta selección de la planta de cabuya para contar con pencas de mayor tamaño que, a su vez, permitan obtener más fibra con menos plantas, con lo cual mejoramos la eficiencia en la producción. El tiempo aproximado de crecimiento es de 5 años antes de ser despencada utilizando una barra de acero con punta filosa.

Para extraer la penca se deben seguir los siguientes pasos:

1. Cut with a machete the stalk closer to the ground.

2. Chop the plant with the help of the bar in the place of the stalk that was cut (Figure 1), until reaching the center; once this is achieved a perpendicular force must be applied on the bar so that the plant opens (i.e., it is lifted), and all the stalks are freed.

3. Remove with the machete the thorns in each stalk.

4. Take the tip of the stalk with the hand and pull it performing a twisting motion until detaching it from its center.

5. Repeat step 4 with all the stalks.

6. Once all the stalks have been extracted, move them to the fiber extraction area.

Figure 1. Extraction of the fiber.

In order to obtain the fiber, the stalks are crushed on a flat surface with the help of a mallet to extract all the water they have inside. Then, the greenish layer that covers the stalk is removed with a machete. With the help of a wooden board, the surface of the stalk is moved up and down to extract water residues and the protective layer, until obtaining the desired fiber, which may show a greenish white color in certain areas, see Figure 2.

Figure 2. Raw fiber.

Once the fiber is obtained, it is cooked for about 100 minutes; then it acquires an intense white color. It is put out to dry during four days in a wire, attaching it with the help of tweezers. It is important that the fiber does not get wet while it is hanged, since its quality may be harmed (Figure 3). When the fiber is completely dry it shows a pale yellow color; it is further combed using a table with nails to separate the smaller fibers, resulting in a uniform fiber, ready to use.

Figure 3. Cooking and drying of the fiber.

2.2. Weaving of the cabuya fiber

A wooden gridded board is used for weaving the cabuya fiber, in order to have the maximum precision when placing the fiber threads. In this case it was a used a weaving at 90 degrees: the cabuya fiber is placed horizontally at a spacing of 2 mm, while the vertical fibers are placed at a spacing of 10 mm; each of the sets should have a total of 4 threads (Figure 4). The final weaving has 40 cm in width x 30 cm in height.

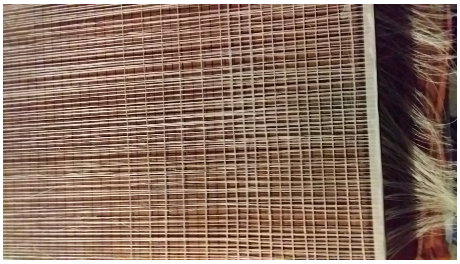


Figure 4. Weaving of the fiber.

Then, the ends of each group of threads are tied, so that the weaving does not tend to deform during further manipulation.

2.3. Manufacturing process of the rearview mirror

The following process is implemented for manufacturing the rearview mirror:

1. Storage of the corresponding resin and fiber.
2. Preparation of the fiber.
3. Preparation of the mold.
4. Preparation of the mixture.
5. Placement of the matrix (cabuya).
6. Solidification.
7. Demoulding.
8. Sanding.
9. Inspection of the finish.
10. Verification of weights.

An integral cleaning of the original rearview mirror is carried out, and then the mirror is disassembled as well as the remaining accessories (Figure 5).

Figure 5. Cleaning of impurities from the original rearview mirror.

When the mold is clean of impurities, it is proceeded to place the mold release wax, as shown in Figure 6, with the purpose of being able to release the rearview mirror from the mold at the end of the drying.

Figure 6. Application of the mold release wax.

The cabuya fiber is used as matrix; for curing of the resin cobalt octoate and methyl-ethyl-ketoneperoxide (MEKP) or catalyst, as a reinforcement two layers of cabuya fiber are used (Figure 7).

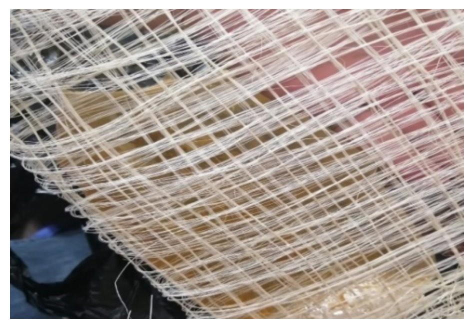


Figure 7. Handmade and hand woven cabuya fiber.

The proportions of resin, cobalt octoate and catalyst must be exact, since the composition shown in Table 1 must be met. A brush is used for applying the mixture, being careful of doing it uniformly to avoid the accumulation in particular areas.

Table 1. Quantities of resin, cobalt octoate, MEKP and cabuya fiber, used for the composite material of the rearview mirror

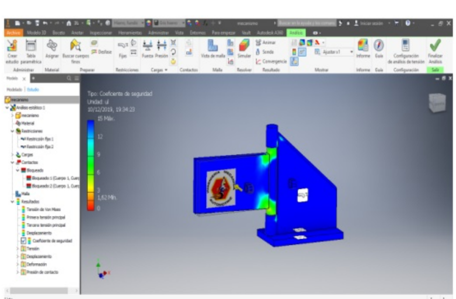
Description	Quantity
Thickness [mm]	2,5
Number of resin layers	2
Woven cabuya fiber [g]	25
Polyester resin [ml]	150
Cobalt octoate [ml]	0,75
MEKP [ml]	0,4

The parameters which with the rearview mirror will be made are specified in Table 1, as well as the quantity of chemical reagents necessary for a higher drying velocity of the resin. Each part of the rearview mirror is left to dry for three days to achieve better consistency and hardness. Following these recommendations, a rearview mirror with better characteristics of resistance and a significant weight reduction was obtained (Figure 8).

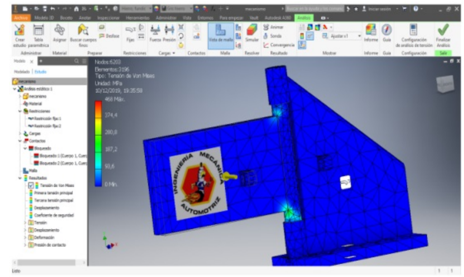
Figure 8. Rearview mirror with a cabuya fiber matrix.

2.4. Design of the mechanism for the 180° rotation

A hinge that continuously opens and closes, similar to the ones used in home doors, serves as the basis for this mechanism, because the rearview mirror should maintain its initial position and recover once it has withstood an impact and has been moved a certain angle from its origin. For this purpose, springs of the same characteristics are placed on the sides of the rearview mirror, so that if it is moved to one side one spring compresses and the other extends, and the mirror returns to its initial state once the application of the force stops. The mechanism is modeled in Autodesk Inventor (Figure 9); it should be analyzed the main points on which the greater stress is exerted when a force is applied on the mechanism. With this information, the necessary precautions are taken in its manufacturing to avoid possible failures during its operation (it may be necessary to reinforce certain areas).



(a)



(b)

Figure 9. Analysis of the mechanism in Autodesk Inventor. a) Safety coefficient. b) Von Mises stress

Figure 10 shows the results of the rearview mirror analysis, which should comply with the NTE INEN 1323 Standard.

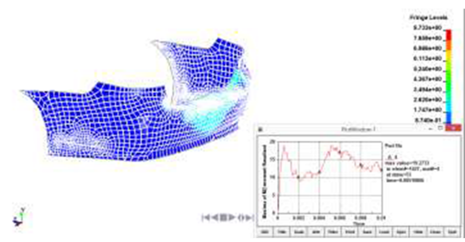


Figure 10. Rearview mirror analysis using the Ansys software.

3. Results and discussion

Table 2 summarizes the comparisons of the weights obtained when using cabuya fiber for manufacturing the rearview mirror, which may be considered as a total success because the measurements obtained show a significant reduction of its weight, thus helping to reduce the weight of the vehicles.

Table 2. Verification of the weights

Description	Weight (kg)
With cabuya fiber and mechanism	0,223
With cabuya fiber and without mechanism	0,1859
Original rearview mirror	0,227

Table 3 shows the behavior of the cabuya fiber rearview mirror when a force is applied on its surface, which enabled to verify the resistance of the 180° rotating mechanism; it was observed that the mounts of the recover springs should be reinforced to avoid the fracture of these small spring holders; similarly it could be visualized that when a larger force is applied on the surface of the rearview mirror it tends to peel off in a small area; the total surface of the rearview mirror is approximately 150 mm^2, on which the resistance analysis will be carried out.

After carrying out the analysis of each of the tests, it could be determined that the cabuya fiber and all natural fibers have low mechanical resistance, and therefore the accessory to be constructed should not be subject to excessive loads.

Table 3. Impact resistance

	Force/area (MPa)	Force (N)
First test	0,039	5,86
Second test	0,019	2,9
Third test	0,01	1,45

The cabuya fiber has a flexible appearance, its manipulation is simple and it does not fracture easily. In contrast, other fibers are rather fragile, they break easily and are rigid, which results in a difficult manipulation. In the case of cane bagasse the length of its fibers is smaller than those of other specimens, which makes more complex its application in the automotive industry; in addition, these fibers have residues adhered to them that correspond to the ducts where the sucrose is stored, causing a less homogeneous structure.

4. Conclusions

The mixture of cobalt octoate and methyl-ethyl-ketone peroxide (MEKP) with the natural cabuya fiber tends to significantly reduce the weight of the rearview mirror and increase its hardness with respect to the traditionally manufactured rearview mirror. The manufacturing cost is reduced in almost 40 % when this fiber is used.

Due to the easiness to handle the fiber and to obtain the materials to be used, the manual stratification is one of the processes most commonly used for manufacturing equipment in the automotive industry.

The selection of the material or of the natural fiber to be used will depend on the particular requirements of the application. The results are encouraging to try to boost the use of domestic natural fibers in the development of other automotive elements (parts), helping to take care of the environment by obtaining biodegradable products.

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