Mechanical Characterisation of Natural Fibre Reinforced Plastics

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Abstract

The work described in this paper refers to the mechanical characterisation of fibre reinforced composite materials with an epoxy matrix. Sisal and Hemp fibres are used with different surface treatments.

The comparison between a reference glass fibre reinforced composite and the other natural fibres composites is made. It is also presented the influence of the surface treatment in the mechanical characterizations of the natural fibres

A brief description of the production of the natural fibres composite materials is made.

Introduction

Today the search for new, recyclable and renewable materials is leading the researchers in new ways. Natural products are emerging and some research is starting in this matter. The work presented here shows the comparison between Glass, Sisal and Hemp [1-2]. Some plates were made using those materials as reinforcement and an epoxy resin as matrix. The natural fibres were cleaned in order to remove straw and other contaminating agents. After these comparisons, we made a surface treatment in the hemp fibres to see if it improves the adhesion fibre - matrix. The treatment used is called mercerization, and is described below. The fibre - matrix adhesion is of the most importance, and the final result of the composite is depending immensely on this factor. The cleaning of the natural fibres is also very important. Contaminating agents can also destroy the composite or reduce its mechanical properties drastically.

Fibre preparation

Glass Mat fibre - the glass fibre is delivered in roles. To prepare the mat to introduce in the mould, we have to cut it in pieces of 150x100 mm^2. The number of layers is very important, to maintain the fibre volume fraction (30% in volume).

Natural Sisal fibre - the first step of any natural fibre is the cleaning. When they were delivered, they were full of grass and other contaminating agents. After the cleaning process, it was necessary to cut the fibres in approximately 30 mm length pieces, to be able to agglomerate them in the mould and make a mat. Making the mat is the next step. After calculating the volume fraction we introduced the fibre aleatory in the mould, close it and put it in the press. After 10 minutes we can remove the mat.

Natural Hemp fibre - exactly the same process as with the Sisal fibres.

The next figures show all the process.

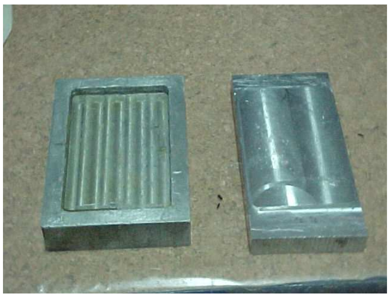

Figure 1: The mould

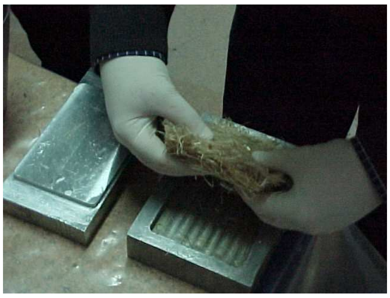

Figure 2: The natural fibre mat

Surface Treatment

With the hemp fibres a surface treatment has been done to increase the fibre/matrix adhesion. This treatment (mercerizing) is made in some steps. First step is to perform an immersion a bath. Two hours in a solution of 8% in volume of Sodium Hydroxide (NaOH) with distilled water. During this process the bath was stirred continuously using a mechanical agitator (figure 3). At the end the solution presented a yellow colour because of the substances removed from the fibre. The next step is cleaning the fibres several times in a distilled water bath, until the water is clean. After several baths, a neutralizing solution of 25% in volume of acetic acid is used. Again, more two or three baths with distilled water and the treatment is finished. To dry the fibres we left them 5 days at ambient temperature, and then six hours at 60º C in an oven (figure 4). [3-5]
The surface of natural fibres is hydrophilic, not giving good adhesion to the hydrophobic epoxy matrix, so the mercerisation treatment try to improve the adhesion fibre/matrix by the decrease of hydrophilic character of the fibres.

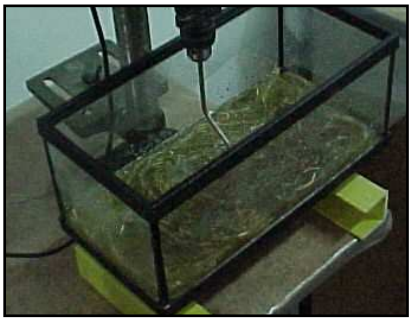

Figure 3: Sodium Hydroxide bath

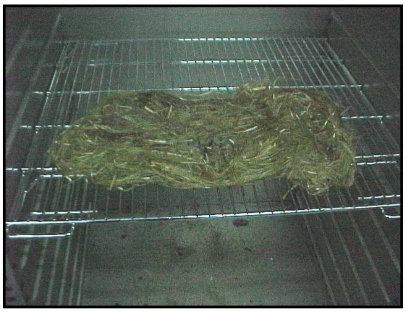

Figure 4: Fibres in the oven

Manufacturing a plate

To manufacture a plate we used the compression moulding technique. The mould that we can see in figure 1 has a cavity of 150x100x4 mm^3 and is made of aluminium. The first step is to clean the surface and then apply the mould release agent QZ13 from Ciba. After the preparation of the resin, we introduce it in the mould (figure 6). The mat is then placed in the mould (figure 7) and the mould closed. At last everything is placed in the hot plate press, where the combination of pressure and temperature make the plate.

Figure 5: Mixing the resin

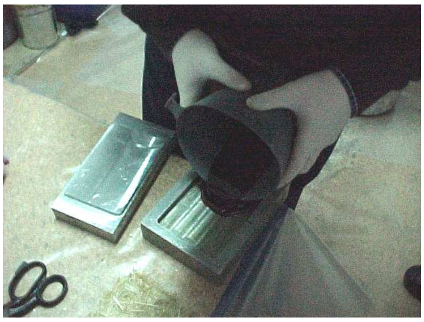

Figure 6: Introducing the resin Figure 7: Placing the mat

After 1 hour in the press, the mould has been open (figure 8) and the trimming of the plate was made. Three examples of the plates are shown in figure 9, one from each material. In all process there were some problems that had to be solved. The first was making a homogeneous mat using the cutted fibres. For 30% volume fraction of hemp fibre we calculated the need of 25 grams. That amount of fibre before compressed is in volume 5 times bigger than the mat we need. The problem wasn't compressing, the problem was maintaining the volume fraction in all the plate. To solve that problem, layers were made with 8 grams each. With three layers we could make a mat, and that reduces the probability of having a very different volume fraction in all the plate. Void content is another problem. Because of the limitation of this process, we estimate by measuring the plate and weighing it that the void content is around 10 %.

Figure 8: Open mould Figure 9: The three plates

To produce the plates used for the comparison, we used the epoxy resin Reapox 520/D526 from REA Industries with the following characteristics:
Tensile Strength (MPa) = 71; Modulus (GPa) = 3.5; Density (g/cm^3) = 1.12.
To produce the hemp plates used for testing the surface treatment, we used the epoxy resin Reapox WOOD RX8 from REA Industries with the following characteristics:

Tensile Strength (MPa) = 50; Modulus (GPa) = 3.0; Density (g/cm^3) = 1.13.
We used a different resin because this new resin has twice the rupture deformation that the first one. We made one or two tests with the 520 and the deformation wasn't enough for the fragmentation tests planed to make with this fibers.

Mechanical Tests and Results

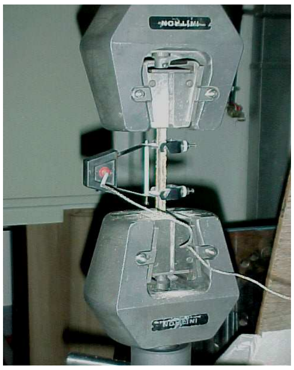

Figure 10: Test setup

For the mechanical tests we used an INSTRON 4208. We made the tests according to the ISO 527-4 standard. We used a 100 kN load cell and a 2 mm/min traction speed. Figure 10 shows the setup.
In our work, we made the comparison between glass, sisal and hemp. In the hemp fibres we have also done a comparison with natural hemp fibres and fibres subjected to a mercerization treatment that is described above.
The results (table 1) show that the natural fibres are still very far from the glass fibre. If we look to the tensile strength, the value obtained by the natural fibres is even inferior than the matrix and more or less four times smaller than the glass fibre. If we look to the modulus, the sisal fibre composite value is half of the glass fibre composite, but the hemp fibre composite is only 20 % inferior.

Composit	**Tensile Strenght [MPa]**	**Modulus [GPa]**	**Deformation [%]**
REAPOX 520/D526 + *30% glass fibre*	192.4 ± 20.5	10.0 ± 0.9	2.5 ± 0.3
REAPOX 520/D526 + *30% sisal fibre*	50.9 ± 5.5	5.5 ± 0.5	1.3 ± 0.3
REAPOX 520/D526 + *30% hemp fibre*	51.1 ± 6.8	7.8 ± 0.5	0.8 ± 0.1
REAPOX 520/D56	70	3.5	4

Table 1: Comparison between the mechanical results of the three fibres

A bad fibre-matrix adhesion could be responsible for these results. Table 2 shows the results of the tests made with the hemp fibres. The surface treatment made to the fibres didn't improve the adhesion between fibre and matrix. In the results we can see a loss of 15 % in the Tensile Strength and a lost of 30 % in the Modulus using this treatment. In both cases the Tensile Strength is inferior to the one of the resin, but the Modulus is higher.
When analysing the crack, we could observe that the adhesion was really bad. In some cracks, we could see small bites of fibre completely removed from the matrix. That shows that the adhesion is inexistent, and that the fibre is weakening the matrix instead of reinforcing it.

Composite	% Fibre [%]	Tensile Strength [MPa]	Modulus [GPa]	Deformation [%]
REAPOX WOOD RX8	25	45.6 ± 0.9	5.4 ± 0.4	0.98 ± 0.03
+	30	45.1 ± 6.3	6.2 ± 0.8	0.90 ± 0.22
Hemp without treatment	35	47.1 ± 3.6	6.7 ± 0.5	0.81 ± 0.15
REAPOX WOOD RX8	25	37.9 ± 1.9	3.8 ± 0.3	0.69 ± 0.02
+	30	38.3 ± 3.9	4.4 ± 0.6	0.64 ± 0.16
Hemp wiht treatment	35	40.7 ± 3.5	4.6 ± 0.3	0.56 ± 0.10
REAPOX WOOD RX8		50	3.0	7

Table 2: Comparison between the mechanical results of the treated and the natural fibres

Conclusions

In this study, in which we compare the composites made with glass, sisal and hemp fibres, we realize that we can't pick a natural fibre, mix it with resin and obtain a composite material. Natural fibres are in reality difficult to process. The results obtained are far from good, in some cases the result of the mechanical properties of the composite were inferior to the one of the matrix.

It is necessary to point the research in the cleaning and in the surface treatment of the fibre. Only with good surface treatment we can obtain a good adhesion fibre-matrix, and that is one key-point to obtain a good composite. In our paper we made the study using the mercerizing treatment of the fibre surface. That treatment proved to be inappropriate, because it didn't improve the mechanical properties, but instead it worsened those properties. Future works should be made to solve this problem.

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