STATISTICAL BEHAVIOR OF HEMP AND SISAL FIBER REINFORCED POLYPROPYLENE COMPOSITES

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ABSTRACT

The use of vegetal fiber incorporated in a thermoplastic resin increases because of the opportunity to recycle old structure. The main problem is the very large uncertainty of the mechanical properties of the fibers. The objective of this work is to establish the uncertainty of the mechanical behavior at coupon-scale to be sure that this kind of materials is interesting for structural applications. Two composite materials have been investigated using hemp and sisal fibers with a polypropylene matrix.
For both materials, although the vegetal fibers exhibit a large uncertainty of their mechanical properties, composite materials using these fibers have a very interesting behavior with a low scattering. The coefficient of variation for all the parameters is less than 7%.
The comparison of both composite materials and polypropylene shows the expected effect of the fibers for the mechanical behavior. It seems that the hemp/PP should be the best choice for structural applications.
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1. INTRODUCTION

The use of vegetal fibers in thermoplastic matrix is increasing mainly because of their environmental advantages and their opportunity to recycle old structures. An another advantage is to provide materials for developing countries were these fibers are abundant. Nowadays, a lot of studies are more focused on the fibers to understand their microstructure and to establish their mechanical properties [1,2]. One of the main results is that these properties exhibit a large uncertainty due to the vegetal nature. For example, it is very difficult to control the diameter of a vegetal fiber. As a consequence, the calculation of the Young modulus remains complex because it requires a constant diameter to calculate correctly the applied stress.
The main question is to determine if the uncertainty, observed at the fiber-scale, propagates through different scales up to the structures providing stochastic properties at the full-scale. Thus, the goal of this work is to carry out several tensile tests on coupons to establish the uncertainty of the investigated materials. Moreover, the influence of crosshead speed was investigated.

2. METHODOLOGY

Two composite materials have been investigated using hemp and sisal fibers with a polypropylene matrix. First of all, a few tests have been performed only on the matrix (polypropylene) to obtain a reference.
The tensile tests have been carried out with different crosshead speeds: 0,5 (noted sample 1) – 1 (sample 2) – 10 (3) and 50mm/mn (4) in order to study the strain rate effect.
Before testing, all the samples have been placed inside a climatic chamber (40°C, 20%humidity) to control the moisture of material.

The evolution of the Young modulus versus deformation was monitored. For that, all samples were unloaded up to 0N for different levels of deformation. The modulus was estimated by calculating the slope of the cycle (Figure 1).

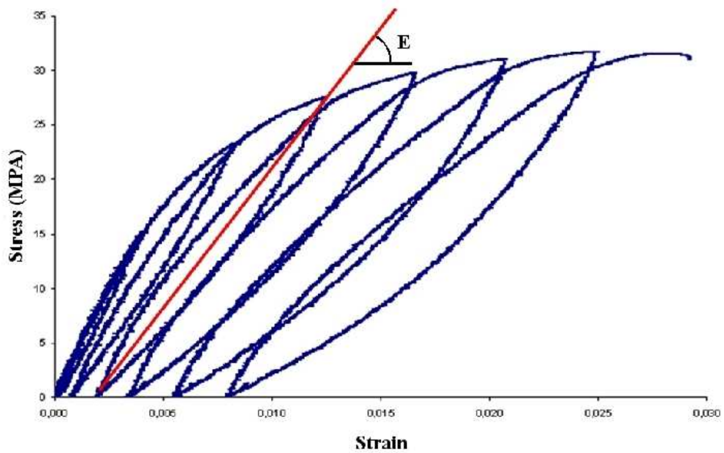


Figure 1: Calculation procedure of the Young modulus.

Displacements of coupons were measured by means of a laser sensor (Figure 2). The light allows the measure of the distance between two targets which are glued on the sample. The strain can then be deduced. This technique allows to monitor large gauge lengths and to protect the sensor during the failure of the coupon. For all crosshead speed 5 samples have been tested to establish an estimated coefficient of variation of the measured properties.

Acoustic emission was monitoring for a sample but probably because of the thermoplastic nature of the matrix no results were acquired.

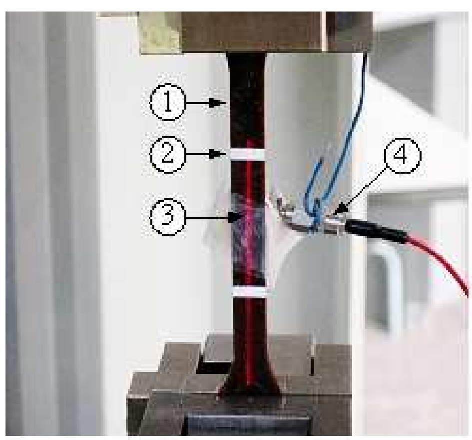


Figure 2: Displacement apparatus: 1) sample, 2) target, 3) laser beam and 4) acoustic emission sensor.

3. MATERIALS

Two materials were investigated.

The first one is a polypropylene (PP) reinforced by hemp fibers and the second one by sisal fibers. The volume fraction of fibers is about 30%. Because of thermoplastic

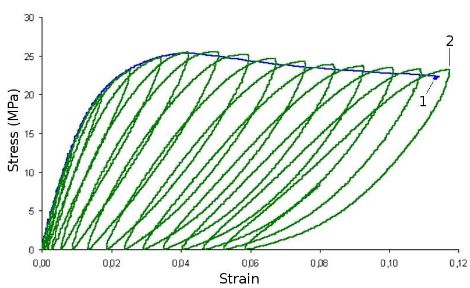
nature of the matrix the process used was injection moulding. That implies the use of short fibers.
The microstructure is quite different in both cases (Figure 3).

Hemp/PP Sisal/PP
Figure 3: Pictures of hemp and sisal/PP composite.

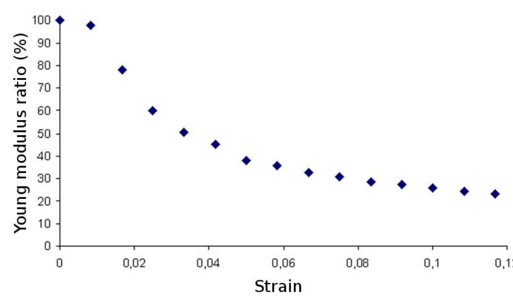
4. RESULTS

1)Polyprolpylene

Several mechanical tests have been carried out on the polypropylene to obtain some references in order to compare with the composite materials.
The curve stress-strain with cycles (Figure 4-a) exhibits a large plastic deformation due to the thermoplastic nature of the polypropylene. A test realized without cycles (curve 1) shows the weak influence of the cycles on the mechanical behavior.



a)



b)

Figure 4: a) curves stress-strain with and without cycles, b) evolution of the Young modulus ratio.

2) Hemp

The first important result is that the expected uncertainty at the sample-scale, taking into account the large uncertainty of the mechanical properties of the fibers, was not observed. On the contrary, the curves stress-strain for a same crosshead speed are very close to each other. Moreover, the figure bellow compares three curves with cycles (sample 2 to 4) and without cycles (sample 1). It appears that the different unloadings don’t affect the mechanical behavior.

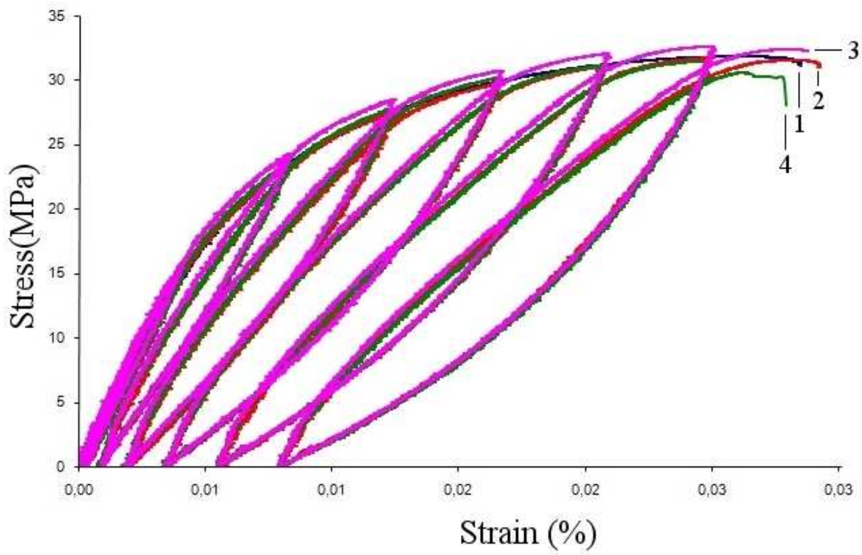


Figure 5: Several curves of the hemp/PP with and without unloading.

The following table (Table 1) gives the coefficient of variation for the different mechanical properties for a crosshead speed of 0.5mm/min.

	Young modulus	Maximum stress	Maximum deformation	Failure deformation
Coefficient of variation (%)	**6.2**	**1.6**	**3.6**	**3.4**

Table 1: Coefficient of variation for the mechanical properties of the hemps/PP.

While the mechanical parameters uncertainties are important at the fiber scale it is quite low at the macro scale (less than 7%). This phenomenon is due to the very large number of fibers which are incorporated into the composite material which induces a mean behavior.

Moreover, the mechanical behavior of this kind of composite exhibits a viscoelastic part as illustrated in the Figure 6. The curve numbers are related to the crosshead speed as described in the methodology chapter.

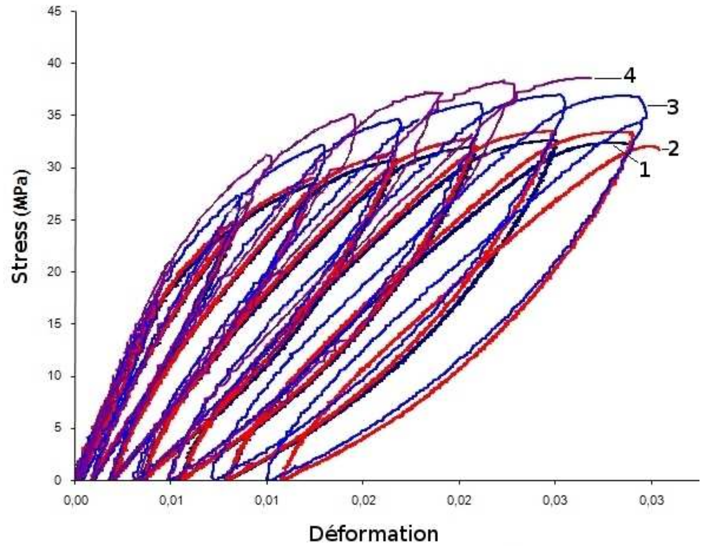


Figure 6: Curves with different crosshead speed.

The increase of the crosshead speed increases the Young modulus more especially at the beginning of the behavior (Figure 7).

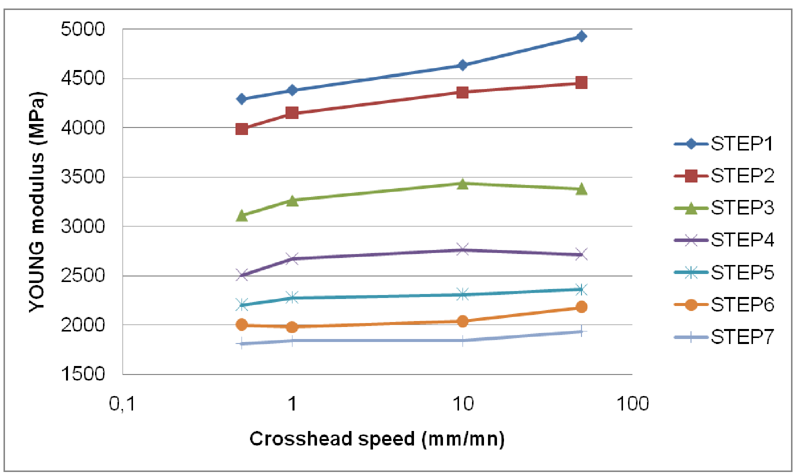


Figure 7: Evolution of the Young modulus versus the crosshead speed for all the cycles (step).

This phenomenon could be explained by the development of the damage inside the material witch modifies significantly the response of the sample as regard to the speed loading. On the other hand, the relative evolution of the modulus for each crosshead speed seems to remain almost constant (Figure 8).

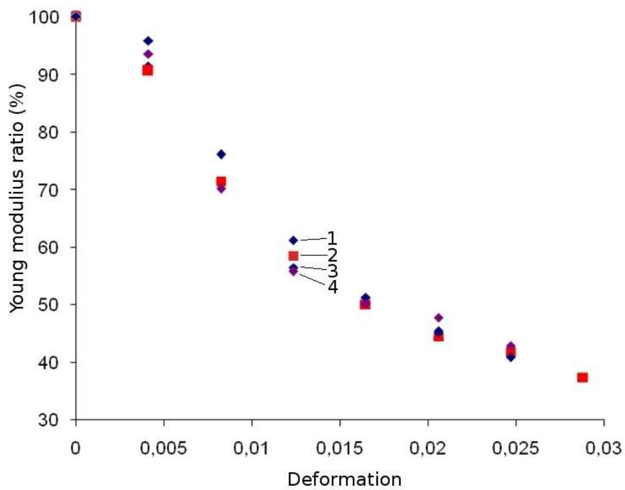


Figure 8: Relative evolution of the Young modulus for all the crosshead speeds.

3) Sisal

We obtain, about, the same conclusions for the sisal (Table 2).

	Young modulus (Gpa)	Maximum stress (Mpa)	Maximum deformation	Ultimate deformation
Coefficient of variation (%)	**4.7**	**1.6**	**1.8**	**10.9**

Table 2: Coefficient of variation for the mechanical properties of the sisal.

As an example, the Figure 9 shows some results of the tensile tests. The curves referenced 1 to 4 represent the sisal for a crosshead from 0.5 up to 50mm/min respectively. In order to compare with the hemp/pp behavior the result for a speed of 0.5mm/min is presented too.

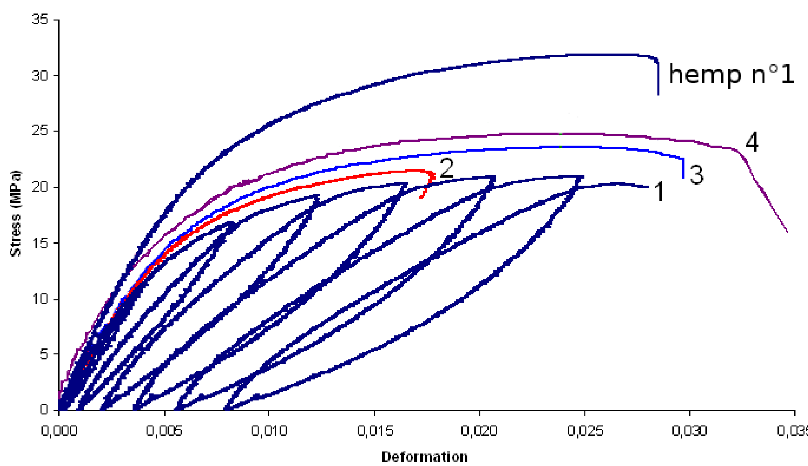


Figure 9: All the curves for the sisal/PP compared with the hemp loaded at 0.5mm/mn.

The comparison of the evolution of the Young modulus versus deformation for all the materials shows that the hemp is the most interesting for structural applications.

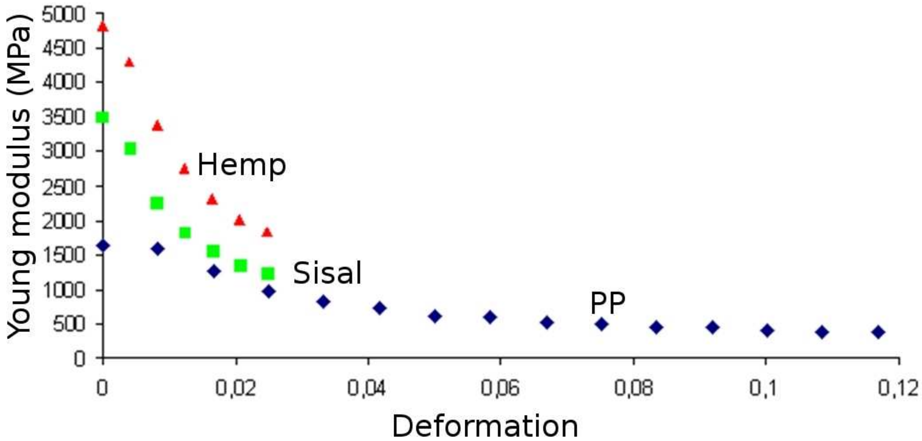


Figure 10: comparison of the YOUNG modulus ratio for the three materials.

CONCLUSIONS

Two composite materials have been investigated using hemp and sisal fibers with a polypropylene matrix.

For both materials, although the vegetal fibers exhibit a large uncertainty of their mechanical properties, composite materials using these fibers have a very interesting behavior with a low scattering.

The comparison of both composite material s and polypropylene shows the expected effect of the fibers for the mechanical behavior. It seems that the hemp/PP should be the best choice for structural applications.

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