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Effect of the Varying Percentage Diss Fiber on Mechanical Behaviour of the Based Polyester Bio-Composite

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ABSTRACT

Improving the mechanical and physical properties of bio-composite materials involves the incorporation of plant fibers such as Jute, Hemp, Kenaf, Ramie, Sisal, Linen, etc. The existence of Diss grass (Ampelodesmos mauritanicus) in abundance in the east of Algeria especially in Khenchela region and taking into account their mechanical resistance and their low density, which justifies their choice of use in composite materials. Tensile and hardness tests for different volume fractions (from 05% to 20%) of short fibers of Diss are performed. The increase in fiber content and their treatment improves the mechanical characteristics of the composite materials. These concentration levels are added to a Polyester resin matrix. Our work relates to the study of a composite material reinforced by a vegetable fiber of which different volume ratio of short Diss fiber are considered. The results collected are purely experimental.

1. INTRODUCTION

Currently the preservation of the environment and the use of renewable resources are the objectives to be achieved by all. The development of materials with renewable resources as reinforcement of composite materials are more and more used in several fields, in particular in industrial activities such as the automobile sector, textile, and furniture etc.

The mechanical properties of composite materials reinforced with vegetable fibers depend on several factors of which we quote: the fiber dosage i.e., the rate of fiber in the material, the length and orientation of these fibers. Several works have supported the use of plant fibers in organic matrices (thermoplastic, thermosetting) or in cement matrices, citing us: Diss [1, 2], Alfa [3], Kenaf [4-6], Lin [7, 8], Jute [9], Date palm [10, 11], Agave [12, 13], Pineapple Leaf [14, 15] Sisal [16].

Nouri et al. [17] in their work show that the Diss fiber bundles with slight diameter and rough surface with the presence of thorns and with low density shows a tensile strength that can reach 270 MPa. They also demonstrate that all the treatments adopted has demonstrated improvements regarding the fibrillation of fiber bundles, their surface state, their thermal stability and practically their mechanical behavior (could reach +60% for Young's modulus and +15% for tensile stress).

Sarasini et al. [18] In their work investigating about the morphology, the thermal, and mechanical properties of the Diss fibers by using an experimental process covering mechanical aspects, mild chemical, and enzymatic steps. They confirm that the structure of Diss fibres make them suitable as a reinforcing filler in polymer composites, which was assessed by manufacturing bio composites with improved stiffness and a tensile strength.

Ashok et al. [19] in their investigation have showed that the addition of nanofiller of Luffa could enhance the mechanical strength of the natural fiber composite.

Salem et al. [20], had studied the mechanical behaviour of Reinforced Alfa fibber with high density polyethylene composites strength by the tensile they showed that the tensile strength of the composites increased with the quantity of fiber in the composite.

Djoudi et al. [21] in their study related to the physical and mechanical characterizations of bio composite materials based on palm fibers, they have found that tensile strength tests of the bio composite material with different fiber percentages (04, 07, 10 and 15%) shows an improvement in the mechanical properties of the virgin resin proportional to the fiber mass ratio up to 10% while a degradation of these properties is detected for a fiber mass ratio of 15%.

Nciri et al. [22] shows that when the polypropylene matrix is reinforced by the addition of short alfa fibers in the range of 05 and 15% by injection process, they found that composite behavior is sensitive to the strain rate, they also found that anisotropy increase when increasing fiber.

The problems related to the fiber / polyester interface because of the amorphous materials that the surface of the fiber contains are reduced by the different treatments, in our case study we used the alkaline treatment (with NaOH) and consequently an improvement in the mechanical characteristics of the composite material is manifested.

2. EQUIPMENT USED

2.1 Metallizer

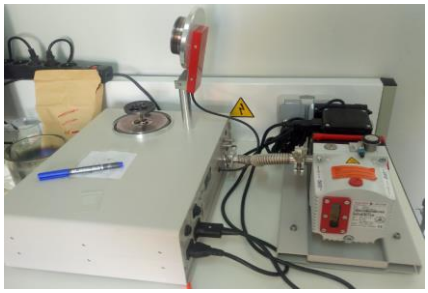


Figure 1. Metallizer

2.2 Scanning electronique microscope

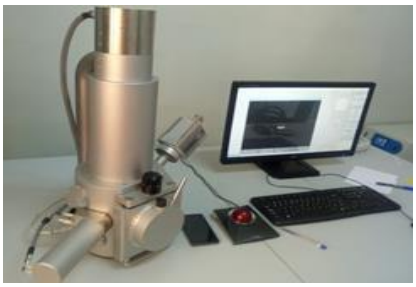


Figure 2. Scanning Electronique Microscope. TESCAN MARK VEGAS 3

2.3 Traction machine

Instron brand 5969 (Figure 3) controlled by a computer at a speed of 1 mm. mm-1 and at a temperature of 23°C.

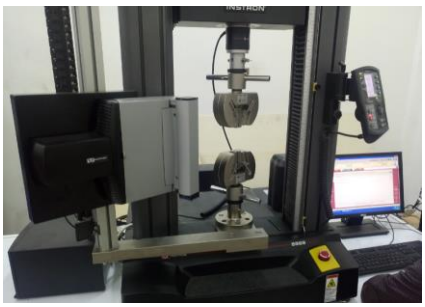


Figure 3. Instron 6959 brand traction machine

2.4 Micro-hardness Tester

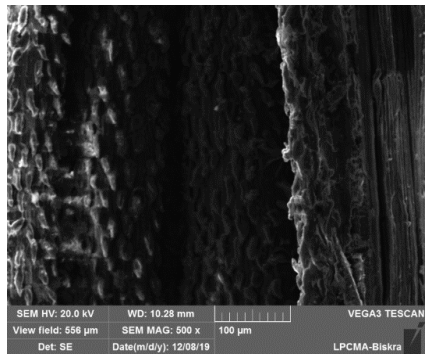
HBVR - 187,5 as shown in Figure 4.

Figure 4. Hardness Tester

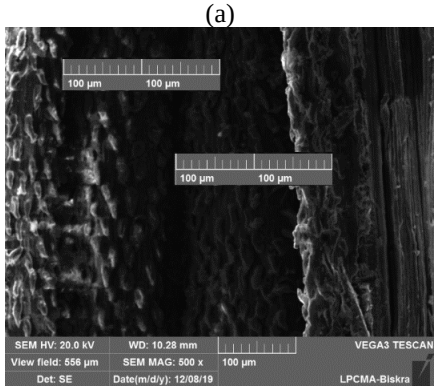
3. RESULTS

3.1 Observations to the scanning electronic microscope

The samples of the different fibers are observed with the ESM (Figure 2) after metallization to make their surfaces conductive (Figure 1), the use of this distinction leads to deducing the morphology and the measurements of the fibers.

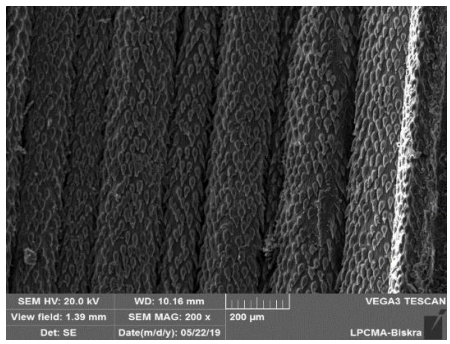


(a)

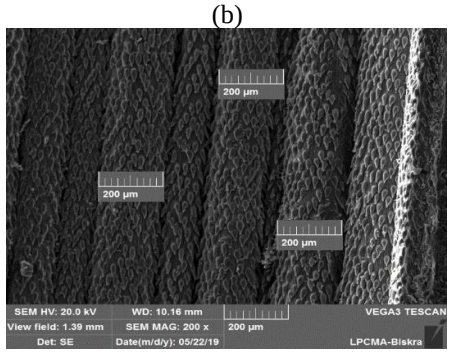


(a')

Figure 5. (a, a') SEM micrograph in longitudinal view of Diss fiber in its raw state



(b)



(b')

Figure 6. (b b') SEM micrograph in longitudinal view of Diss fiber after treatment with NaOH

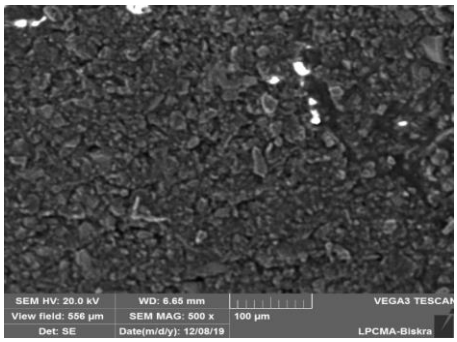


Figure 7. SEM micrograph transverse view of Diss fiber in its raw state

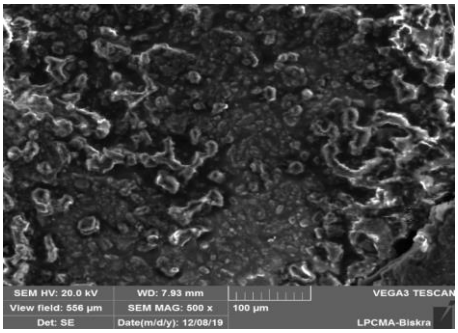


Figure 8. SEM micrograph transverse view of Diss fiber after treatment with NaOH

Figures 5 to 8 Illustrate the difference between Diss fibers in their raw and processed states. The surfaces of the raw fibers are smooth because of the wax and cellulosic component, on the other hand the treated fibers have rough surfaces of snakeskin.

The figure a 'and b' are exposed to justify the measurements of the diameters of the fibers.

3.2 Traction test

The traction test is the most used for the characterization of materials to deduce their mechanical parameters, this test consists in subjecting a specimen to a unidirectional traction force until failure.

This test allows to study in detail the influence of the additions of fibers to the matrix and to observe the evolution of the mechanical characteristics of the bio-composite material.

3.2.1 Production of test Specimens

The traction specimens are cut according to the ISO 527-2 B1 standard (Figures 9, 10 and 11), these specimens have different volume fraction as a percentage of fibers. The specimens are on average six specimens for each type of test.

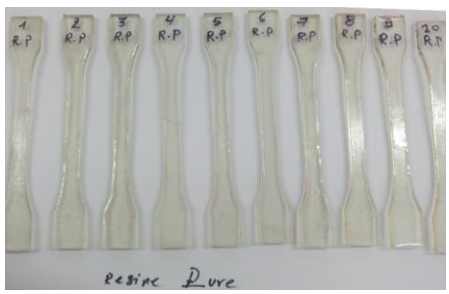


Figure 9. Tensile specimens in Polyester resin

Figure 10. Tensile specimens reinforced with 05% untreated Diss fiber

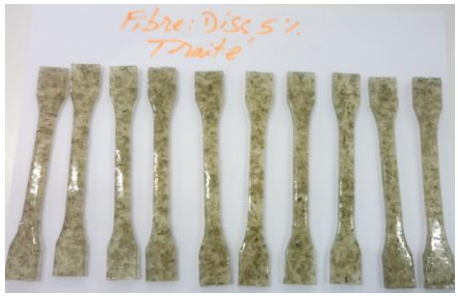


Figure 11. Tensile specimens reinforced with 05% treated Diss fiber

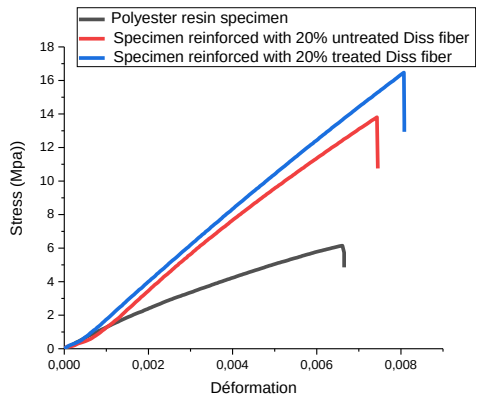


Figure 12. Stress-strain curve of the resin and at 20% of treated and untreated Diss fibers

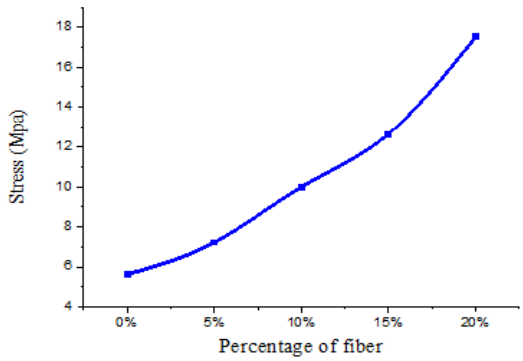


Figure 13. Variation of the stress at break as a function of the fiber rate of Diss

The stress-strain curves of (Figure 12) represent an example of the results obtained from the tensile test on the reference specimen (Polyester resin) and two specimens with a volume content of 20% of fibers of Diss treated and untreated (Figures 13, 14).

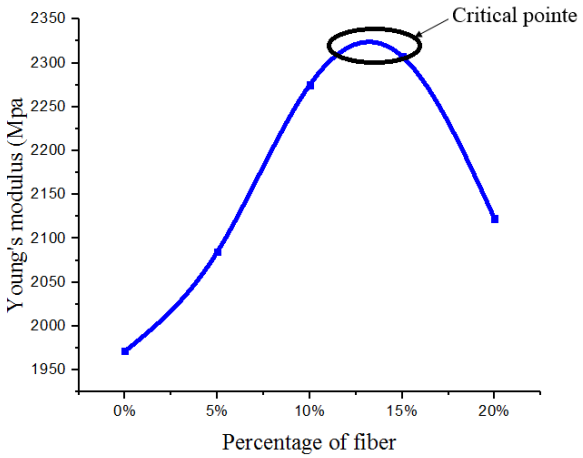


Figure 14. Variation of the Young's modulus E as a function of the fiber rate of Diss (from 0% to 20%)

Note: Given the decrease in the value of Young's modulus for the range of (15% - 20%), which presents a degradation of the matrix's material, we limit the study to the range of the volume fraction (from 0% to 15%) (Figure 15).

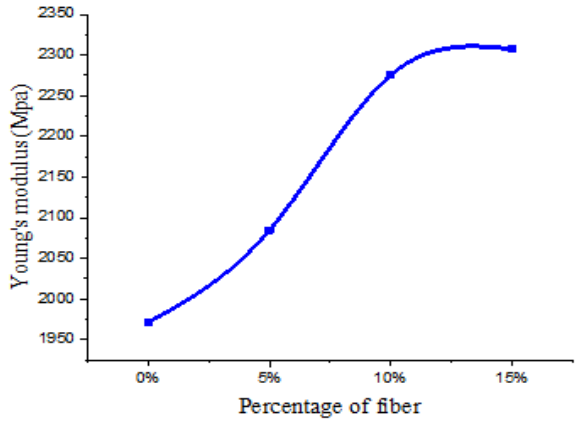


Figure 15. Variation of the Young's modulus E as a function of the fiber rate of Diss (0% -15%)

3.3 Hardness test

The hardness tests are made to know some properties of the material such as its ductility and resistance to penetration. They are carried out by an HBRV-187,5 Hardness Tester (Figure 4). These tests are carried out for test pieces with different percentage of Diss fiber content in their raw and processed states. Four specimens for each type of material are tested. Six measurements are taken for each specimen, therefore 26 readings for the same specimen. Brinell hardness value is given by predefined tables (Tables 1 and 2) after calculating the product of the difference in reading on the microscope multiplied by the amplification coefficient of the microscope.

$$L = (L_{MAX} - L_{MIN})I \rightarrow HB \quad (1)$$

I=0.004 when the objective is 2.5x.

I =0.002 when the objective is 5x.

We can also calculate the Brinell hardness by the following expression:

$$HB = \frac{2f}{\pi D\left(D - \sqrt{D^2 - d^2}\right)} 0{,}102 \quad (2)$$

Table 1. Brinell hardness values for a specimen at a rate of 20% of Diss fibers

Specimen number	Test number	HB Calculated	HB given
01	01	26.5738	27.060
	02	31.2200	31.800
	03	22.0022	22.436
	04	27.1612	27.680
	05	33.8459	34.400
	06	23.9708	24.440
02	01	28.4978	29.700
	02	25.8179	26.360
	03	28.3917	28.090
	04	30.1578	30.760
	05	29.7021	30.260
	06	20.8574	21.260
03	01	25.2705	25.740
	02	24.1387	24.600
	03	30.6235	31.200
	04	29.8151	30.380
	05	29.7585	30.300
	06	29.3112	29.880
04	01	22.0022	22.440
	02	19.6008	19.900
	03	27.0620	27.560
	04	28.2862	28.820
	05	24.1387	24.600
	06	25.3312	25.660

Table 2. Average values of hardness for each type of specimen

Specimen	Test number	Average values of hardness	Specimen's Average values of hardness
0%	01	19.3098	18.8436
	02	18.0453	
	03	19.2854	
	04	18.7341	
5%	01	21.1733	22.3700
	02	22.3656	
	03	24.1993	
	04	21.7417	
10%	01	24.1578	24.9071
	02	25.1338	
	03	23.9764	
	04	26.3604	
15%	01	26.3232	26.2257
	02	24.5882	
	03	25.5681	
	04	28.4234	
20%	01	28.2176	27.8159
	02	29.0632	
	03	26.7600	
	04	27.2227	

4. EVOLUTION OF TENSILE AND BRINELL HARDNESS TEST

Table 3. Summary of tensile and Brinell hardness test results

Percentage of fiber (%)	Young's Modulus	Elastic limit (Mpa)	Brinell hardness
0%	1971.4575	5.6357	18.8436
05%	2084.6672	7.2256	22.3700
10%	2275.1158	10.0025	24.9071
15%	2307.4627	12.6573	26.2257
20%	2122.4578	17.5084	27.8159

In this part we expose some results of tensile and Brinell hardness characterization of our bio composite specimens, as shown in Table 3.

5. DISCUSSIONS OF RESULTS

The two Figures 13 and 14 show that the density fractions increase of diss fibers in the polyester matrix improves the strength and modulus of elasticity.

Concerning the hardness testing, by analyzing the measurements of the various tests carried out, we can say that on average the hardness values increase as a function of the volume rates of the Diss fibers (Figure 16), this increase is linked to the hardness of the fibers. It is also noted that the values of the Brinell hardness are not stable for the simple reason that the indentor sinking depends on the contact zone. These values vary depending on whether the fiber is very near or far from the pressure zone. Because the fiber of Diss is considered more rigid and therefore opposes the indenter. The hardness is stable around 19 HB for the resin, on the other hand there is a high probability of having values greater than 25 HB and a low probability of having values below 25 HB for a volume fraction of fiber greater than 20%. On the contrary, there is a high probability of having values of about 20 HB and a low probability of having values greater than 25 HB for volume fractions of less than 10%.

The evolution of the Brinell hardness values as a function of the elastic limit and the evolution of these same values as a function of Young's modulus are proportional and in agreement (Figure 17) and (Figure 18).

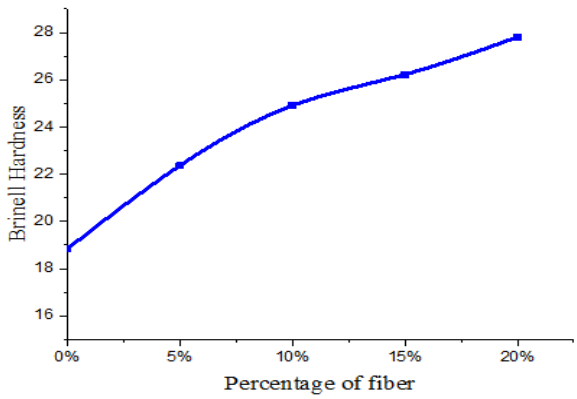


Figure 16. Change in Brinell hardness with volume fraction of Diss fibers

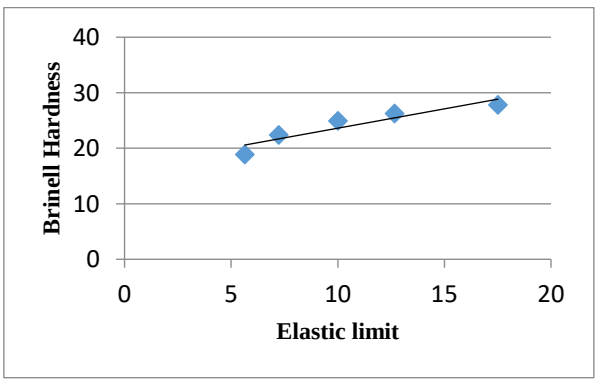


Figure 17. Evolution of Brinell hardness and elastic limit

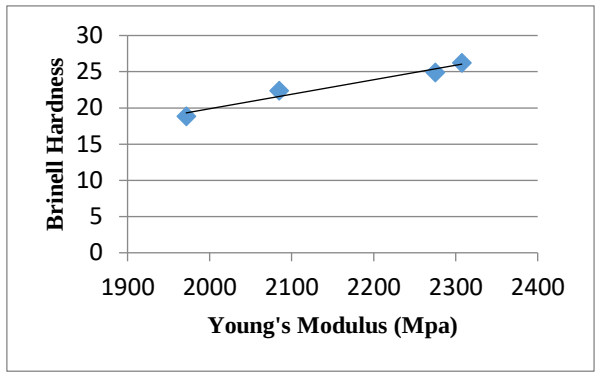


Figure 18. Evolution of Brinell hardness and Young's Modulus

6. CONCLUSION

Following the results presented in the case of our study which stipulates the variation of the percentage of Diss fiber in the Polyester matrix we conclude:

Relating to Figures 5 and 6 which represent scanning electron microscopy images containing Diss fibers in their states before and after treatment with NaOH, we deduce that the fiber volume increases diametrically due to the absorption of liquid NaOH solution. This increase is evaluated at a quarter of its initial volume.

The impact of the indenter is greater in the surface containing just resin than on the surface containing fiber, which explains the increase in the hardness value in the presence of the Diss fiber.

The increase in mechanical parameters such as: Young's modulus E, stresses and strains is proportional to the increase in the rate of Diss fibers.

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