The Influence of Different Mercerisation Temperatures on the Mechanical Properties of Woven Jute Fabric / Polyester Composites

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THE INFLUENCE OF DIFFERENT MERCERISATION TEMPERATURES ON THE MECHANICAL PROPERTIES OF WOVEN JUTE FABRIC / POLYESTER COMPOSITES

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ABSTRACT

The assembly of two different materials (matrix and reinforcement) develops an interface zone. At this zone, important parameters such as the coefficient of thermal expansion, the modulus of elasticity, the density differ from one face to the other. As a result, much research has been conducted to understand and evaluate the effect of interfacial bonding on the mechanical behavior of composites. The major drawback of the development of these plant fibers is to inject fibers as reinforcement with hydrophilic character into polymer matrices with hydrophobic character. In this regard, several methods of modifying plant fibers alter the interfacial bond between the fiber and the matrix. These various physical or chemical treatments having the roles of cleaning, reducing water retention, increasing the anchoring of the fiber, make it possible to obtain good fiber-matrix adhesion and consequently to improve the mechanical properties of the composite materials.The main interest of our empirical work is to examine the influence of the effect of different temperatures (30, 60, 90, 120, 160, 200) °C on the alkali content of the chemical treatment of 5% NaOH during 2 hours on the biochemical composition of fibers as well as the mechanical behavior in traction of jute/polyester fabric composites.

Keywords: *Composite, Mercerisation, Vacuum molding, chemical treatment, jute.*

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1. INTRODUCTION

Lately, the integration of plant fibers as reinforcement in thermoplastic or thermosetting matrices provides composite materials. They have great interest which has increased rapidly in various applications due to their privileges such as non-toxicity, design flexibility, excellent strength-to-weight ratio, corrosion resistance, easy fabrication and light weight [1-]. Much work has been done on the use of natural fibers for polymer composites [2–5]. Vegetable fibers such as jute, esparto, diss, Spanish genie, palm, sisal, silk, bamboo, flax and banana have been shown to be an effective reinforcement for polymer composites by many numerous works [6–8]. In addition, surface reinforcements offer resistance to cracking or transverse forces and therefore obtaining stable properties [9, 10]. Jute is among the various vegetable fibers which appears to be an encouraging fiber due to its high mechanical properties and its tenacity compared to other natural reinforcements and its abundance. Jute fiber composites can be found applied in household items, automotive parts, thermal insulation and in door panels [11]. Despite all the advantages, natural fibers have the disadvantage of water absorption. They are hydrophilic in nature, as they are derived from cellulose, which contains highly polarized hydroxyl groups. The poor fiber/matrix interfacial adhesion caused by this problem during mixing limits the use of these fibers as reinforcement material in bio-composite materials [1]. Several surface modifications approach such as physical treatments, chemical treatments are used to increase the interfacial adhesion between the natural fibers and the matrix. These treatments have been the subject of many works in the bibliography citing as an example, heat treatment, plasma treatment, acetylation, alkalinization, silane [12-15].

The surface-treated fibers decrease their hydrophilicity and therefore present the composites with superior mechanical properties compared to those of composites reinforced with untreated fibers [16-17]. Alkaline treatment is one of the simple and inexpensive chemical treatments for natural fibers in better reinforcement [18]. It reduces the diameter of the fiber and generates roughness on the treated surface due to the breaking of hydrogen bonds in the network structure. Afterwards, the adhesion of the fiber-matrix interface has improved and this leads to an increase in the mechanical properties [19].

In this work, natural fiber composites were obtained by vacuum infusion using alkali-treated jute fabrics. The effect of treatment temperature on the mechanical properties of polyester-based fibers and composites has been studied.

2. EXPERIMENTAL TECHNIQUES

2. 1. Used materials:

The materials used are:

- Jute fabric in a roll of a plain weave as reinforcement supplied by (The materials used are: EPE-Bejaia VARIOUS TEXTILES ALGERIA S.P.A.) (Fig.1) cut into dimensions (300x250).

mm

Fig. 1. Jute fabric with dimensions 300x250 mm

- Unsaturated polyester resin as matrix (supplied by MAGHREB-PIPE Industrie M’sila, AlGERIA).
- Sodium hydroxide (NaOH).

2. 2. Mercerization of jute fabrics:

In this work, we used the alkaline chemical treatment of tissues with a concentration of 5% NaOH solution for a period of 2 hours and a temperature variation of (T° = 30°, 60°, 90°, 120° ,160° and 200°C) (Fig.2).

Fig. 2. Impregnation of jute fabrics in the 5% NaOH / 2 h solution with T° = (30, 60, 90,120, 160 and 200) ° C

2. 3. Implementation of the bio-composite

The preparation of our bio-composites with polymeric matrix is done after alkaline chemical treatment of jute fabrics, with different temperatures using vacuum molding. The implementation of the material is carried out within the mechanical engineering molding laboratory (University of M'sila, Algeria).

2. 3. 1. Preparation of the reinforcement :

After cutting and alkaline treatment of the fabrics, they are hot pressed using a press in the same laboratory to ensure a planar orientation of the fibers. The temperature and pressure used are of the order of 100°C and 4 bars respectively for 5 minutes (Fig.3). These operations confer a certain isotropy and make it possible to reduce the thickness of the folds as well as the elaborate composite material.

Then the reinforcement is steamed for 20 min at 100°C, in order to release the humidity. The latter is harmful because the matrix used is hydrophobic.

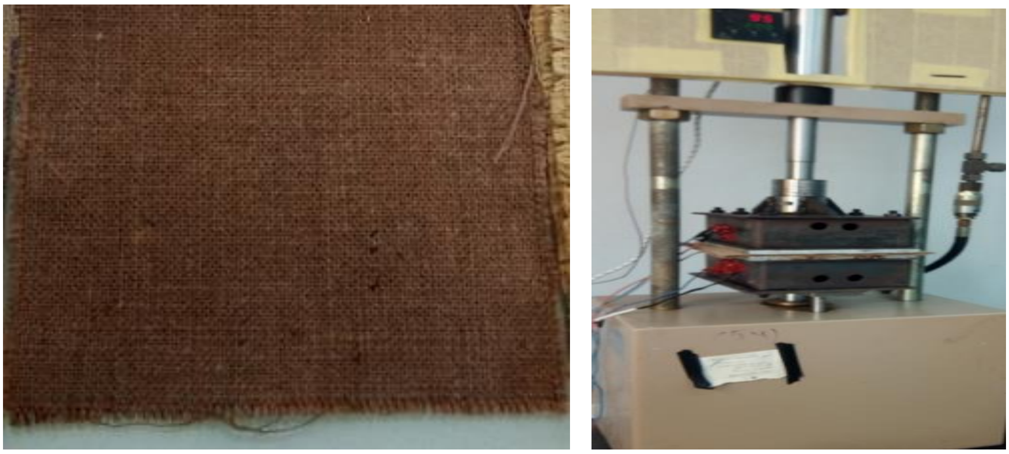

Fig. 3. Pleats of pressed jute fabrics

2. 3. 2. Preparation of the resin:

In our case we used polyester resin with 2% hardener (Fig. 4)

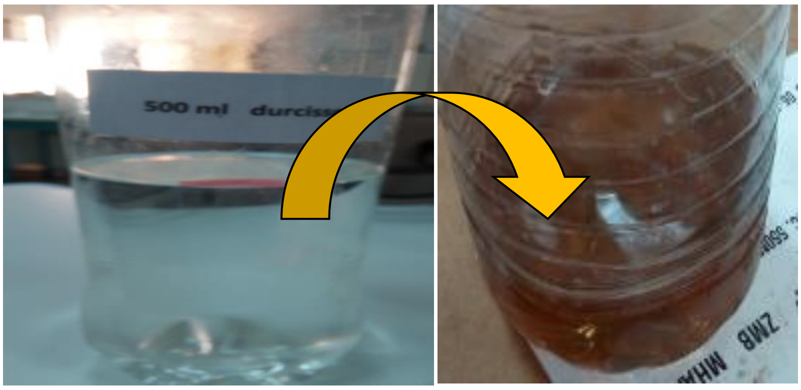

Fig. 4. Preparation of the polyester resin (2% hardener + resin).

2. 3. 3. Elaboration of biocomposites:

In this work, the technique of vacuum molding was chosen (Fig. 5). The vacuum mechanism consists of gradually replacing the vacuum with resin, which is why the assembly must be sealed under a plastic film. After the complete replacement of the vacuum by the resin, the plate remains under vacuum pump until the complete vitrification of the matrix.

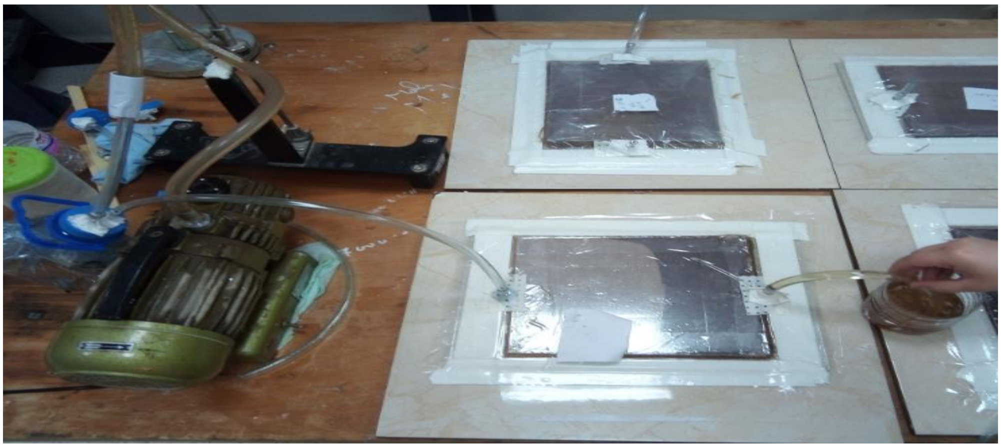

Fig. 5. Vacuum molding device.

The final plates we obtained are shown in Fig.6.

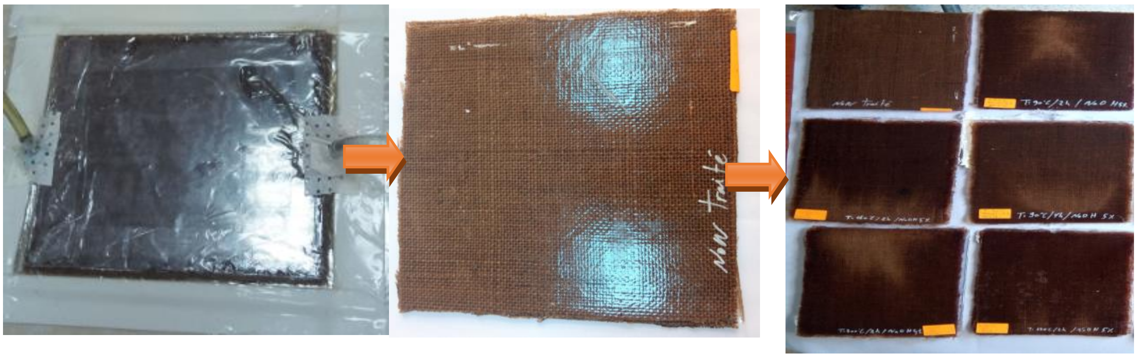

Fig. 6. End plates of woven jute/polyester bio-composite.

2. 3. 4. Preparation of specimens

In this part we cut 4 specimens for the tensile test. Once the resin has completely polymerized, the samples are taken from the plate using a permanent marker. Standard (150mm*25mm) (ASTM) tensile test specimens are cut using steel strips. (Fig. 7) and (Fig. 8).

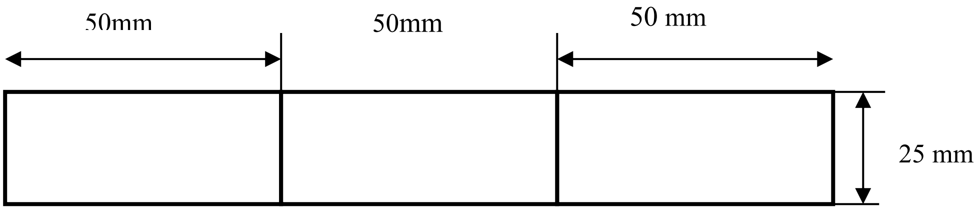

Fig. 7. Dimensions of the specimens (ASTM).

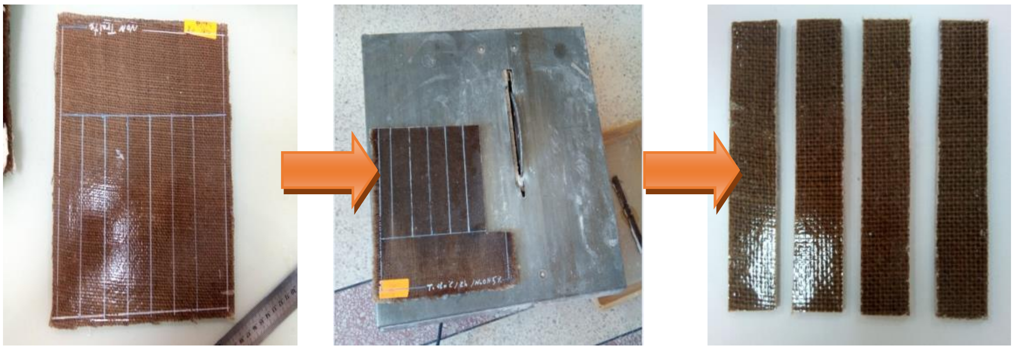

Fig. 8. Cutting operation.

2. 4. Mechanical characterization

In this part we will present the mechanical test which was carried out on the specimens which were cut out for the determination of the mechanical characteristics of the materials used. The tests were carried out at the level of the research-unit-of-emerging-materials at the University of Sétif in Algeria.

2. 4. 1. Tensile test

The specimens are prepared according to the ASTMD3039 standard where we used flat specimens whose length of the useful section is an order of magnitude (i.e. 6 times) greater than the width. Tensile tests were carried out until the specimens broke at a speed of 2 mm/min. Young's modulus and tensile strength were evaluated under ambient conditions. Three specimens were tested. The tensile tests were carried out using a universal tensile machine (MTS Traction formation 106), at a tensile speed of 2mm/min (Fig.9.). Young's modulus is calculated from the linear area of the stress-strain curve.

Fig. 9. Specimen subjected to the tensile test.

3. RESULTS AND DISCUSSION

3. 1 Mechanical characterizations.

In this paragraph, the results of the mechanical tests, obtained following the tensile test of the bio-composites, are illustrated and discussed.

3. 1. 1. Analysis of stress-strain curves of bio composite

The tested specimens obtained from the elaborated biocomposites are characterized at different mercerization temperatures for 2 hours and with 4 plies in the warp direction. At least three specimens of the same treated sample tested in tension. During this test, the specimens were loaded in monotonic tension until failure.

Figure 10 is an example which represents the three curves of the evolution of the stress according to the deformation (σ-ε) of the samples (jute/polyester) at T=30°C, tested in tension in the warp direction.

These curves show that the material exhibits a nonlinear behavior independently of the state of the tissue (treated). This nonlinearity is not due to plastic deformation as in the case of ductile metals, but it results from microscopic damage such as fiber breakage, matrix cracking, fiber/matrix interfacial decohesion and delamination, which can occur at relatively low stresses. These damages increase in size at different points in the composite as the stress increases. They do not cause immediate fracture of the composite, but its rigidity gradually decreases. Such behavior has been reported by Mallick et al. [20]. The distribution of this microscopic damage is strongly influenced by the mercerization temperature due to the change in affinity between the fiber and the matrix.

The stress and strain curves of the three specimens of the same sample have similar and almost identical behaviors, with a small dispersion surely it is due to the stages of vacuum elaboration. The evolution occurs in three stages, there is, at the beginning, a curvature up to a certain value, which is of the order of 0.5% of the deformation, then a linearity characterized by an increase up to the stress maximum. The latter varies almost as the strain increases until it reaches its maximum value when a sudden rupture is reached.

The average stress values are respectively around 17.96, 19.55 and 17.05 for the biocomposites at T = (30°C, 90°C and 200°C). The Young's coefficient was calculated in accordance with the ASTM 3039 standard and the main mechanical properties obtained are listed in Table 1.

Table 1. Mechanical properties of the studied bio-composites

Ep	Module de Young (GPa)		Contrainte (MPa)		Déformation (%)	
	E moy	Écart type	Contmoy	Écart type	Déf moy	Écart type
30°C	1,7962	0,0854	17,9664	0,2708	2,3985	0,9902
60°	1,4225	0,1365	17,0767	1,8428	3,4369	1,0815
90°C	1,9021	0,0055	19,5523	1,7023	2,0186	0,1151
120°C	1,4735	0,2243	20,2225	1,8274	5,5768	1,3135
160°C	1,5592	0,1033	19,6076	1,1092	5,5483	0,2362
200°C	1,5684	0,1894	17,0510	0,2035	3,2654	0,7220

The results of the tensile tests indicate the mechanical behavior of the biocomposite specimens reinforced with jute fabrics treated with different temperatures.

Figure 11 gives us the comparison between the curves of different mercerization temperatures. The stress-strain behavior shows that the sample at a mercerization temperature of 90°C gives us better mechanical properties than other mercerization temperatures.

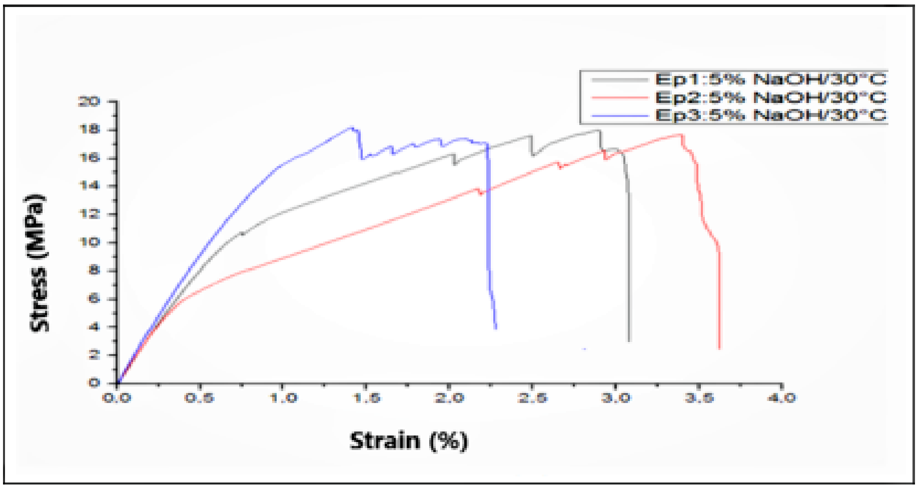

Fig. 10. Evolution of stresses as a function of deformation (σ-ε) of specimens subjected to traction (30°C) for 2 hours at 5% NaOH.

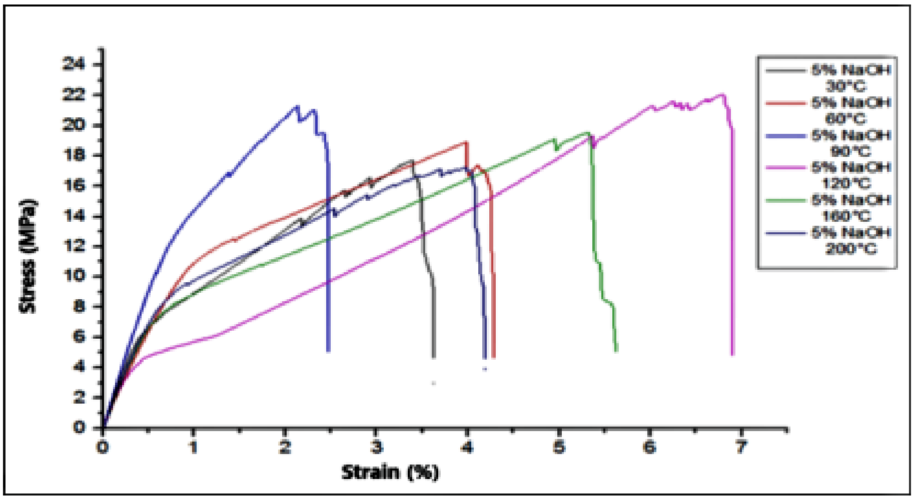

Fig. 11. Stress-strain curves as a function of different mercerization temperatures.

3. 1. 2 Break parameters

The histogram in figure 12 shows that in the variation of the mercerization temperatures of the reinforcement fabrics, the Young's modulus of the Polyester/Jute bio-composite varies. This results in the effect of the mercerization temperature of the reinforcement fabrics on the production of bio-composites.

As can be seen in Figure 13, the stress increases in the bio-composite at 120°C to reach a maximum value of around 20.22 ±1.83MPa.

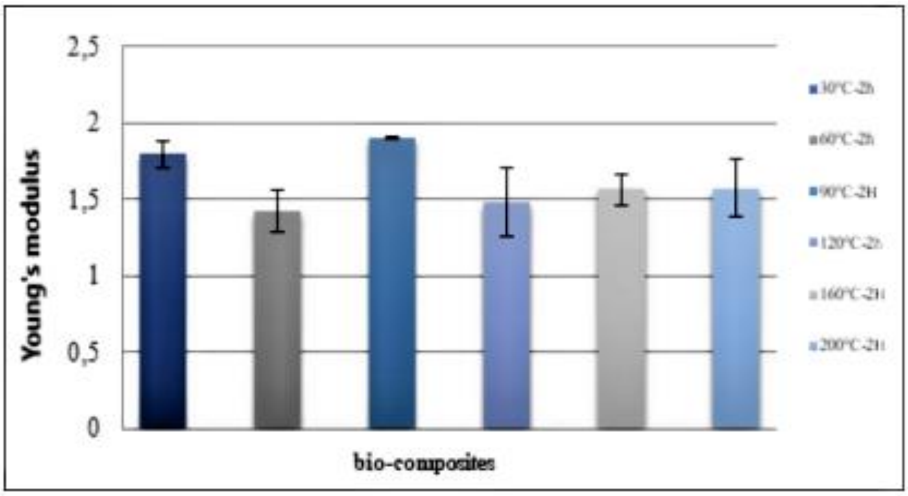

Fig. 12. Histograms of the evolution of Young's modulus of bio-composites.

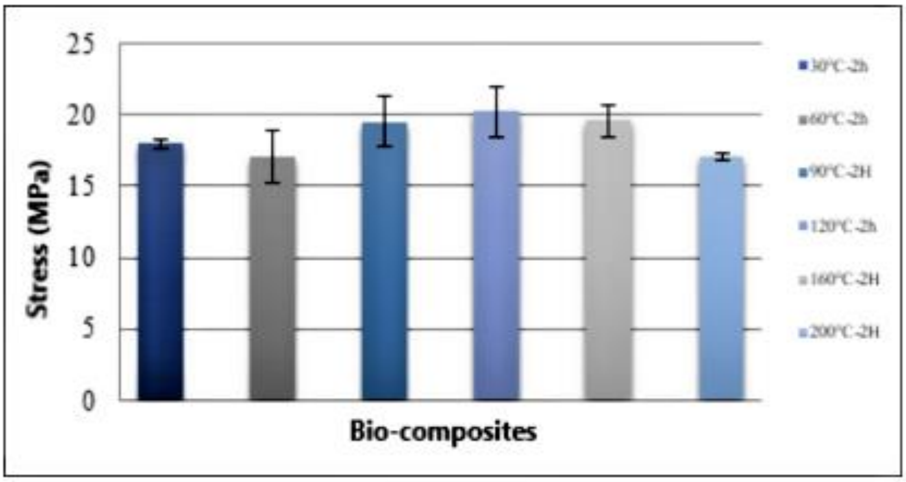

Fig. 13. Histograms of the evolution of bio-composite stresses.

4. CONCLUSION

In order to improve the adhesion between the fabrics and the matrix, the fabrics are subjected to different treatment temperatures. Different composites are therefore made from fabrics treated with soda. If we now compare the mechanical properties of our biocomposites for different temperatures, we can say that:

The tensile strength is better with the alkalinization temperature of 90°C (5%NaOH for 2h) compared to other temperatures. The Young's modulus and Conyrainte values at rupture of these biocomposites are equal to 1.90 GPa and 19.55 MPa respectively. This indicates that this temperature of the soda treatment leads to a better modification on the mechanical properties of this biocomposite. This was demonstrated by our results cited above.

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