

## Quasi-static mechanical characterization and fatigue of a composite laminates

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### ABSTRACT

*This present work focuses on the quasi- static mechanical characterization and or fatigue of a composite materials (laminate) jute/polyester manufactured under vacuum and with stacking sequences of 0/ 90. The obtained results of tensile tests on the laminate, showed a similar behavior on two levels: a linear portion up to 20 MPa and a nonlinear portion to rupture at 47 MPa  $\sigma$  max , followed by elongation of 2.08 % with a break elongation up to 2.50 %. Also, it was noted that increasing the temperature of the samples (5-6 ° C ) when the fatigue test remains in ISO 13003 , which requires a temperature increase of less than 10 ° C. the results of fatigue test showed also that with a loading of 50% of the maximum load reached more than one million cycle, the more load is increasing the cycle numbers of decreases.*

**Keywords:** Fatigue, jute, polyester resin, mechanical behavior, static and dynamic.

### INTRODUCTION

The fibers used as reinforcement in polymer matrix composite materials are primarily synthetic fibers such as carbon fibers or glass . However, other fibers can be used as plant fibers have mechanical , physical and chemical properties of interest as well as some economic and environmental [1] benefits. Among the commonly used plant fibers , those obtained from the plant of jute have good mechanical properties . Among all the natural fibers ,are the jute has good mechanical properties such as tensile and bending strength [ 2 ] . In addition, the imported raw jute is processed, spun and woven in Algeria , it is available at low cost .

Composite materials reinforced with synthetic fibers , particularly , those of glass , are currently widely used in the production of composite parts . However, their use raises more questions as the health and environmental perspective [3].Energy consumption during the production of these fibers is high and is associated with the emission of Volatile Organic Compounds (VOCs) harmful during their implementation. The work undertaken by Mir [4] et al Study of mechanical and thermo mechanical properties of Jute/epoxy composite laminate. Baley et al [5] show that the properties of natural fibers change considerably and this variability occurs starting from their harvests [6]. Khöler et al [7] show that the genetic variability of jute fiber is related to the nature of jute. One of the principal problems of manufacture of jute fabric resides in the optimization of its use. To get the better mechanical properties the optimization of fiber use is significant [5-6].

The behavior of jute fiber is controlled by two parameters, one is the reorientation according to the axis of fibril the second is the slip compared to the others [8,9]. Earle et al [10] show that the angle of microfibrillaire of the jute was influenced by the percentage of cellulose in the jute (61% to 71%). The Work of Broutman et al [11] showed that this angle of microfibrillaire was generally about 8 degrees and influences the mechanical behavior of the jute. For the improvement of the mechanical properties of the jute, especially its behavior in wet medium, several works were initiated to treat the surface of the jute fiber [12,13]. These treatments which modify the interphase of the surface of fiber produce morphological changes [14-15]. Treatments were carried out using alkaline, silane or alkaline

andsilane [12,18] which have decreased the absorption of moisture from 4.2 to 3.8 %. The breaking stress of a fabric treated with silane is better than that of fabric untreated, on the other hand the breaking stress of a jute fabric untreated is better than a jute treated with alkaline [16,17,18,19]. Other treatments were also done under UV radiation presented an increase of 58% of its flexural strength [20-21-22]. The uses of jute reinforced plastic are the current interest of many researchers. The most used thermoplastic resins are polyethylene (EP) [23, 24], polypropylene (PP) [25, 26], polystyrene (PS) [27, 28], vinyl polychloride (PVC) [29, 30] and the polyester [31, 32, 33] for economic reasons.

There is currently no economically viable solution for reprocessing traditional reinforced fiber composites end of life, without transfer of pollution. Then an alternative is to use natural fibers, which are derived from renewable biocomposites and stable resources at the end of life, and therefore more environmentally friendly. Thus, replacing synthetic fibers with plant fibers, allow to reduce the environmental impact of reinforcements.

Natural fibers offer promising prospects through their interesting specific properties due to their low density, but also to their biodegradability [34].

Despite the growing interest in bio-based materials, it nevertheless appears that few studies have examined the fatigue behavior of jute fiber reinforced biocomposites. In this context, the present study deals with the fatigue of composite jute / polyester. It begins with the quasi-static characterization of a laminated jute / polyester, before describing the ability of the composite to undergo stress tensile fatigue. Pending a more efficient ecological resin, our choice fell on a thermosetting polyester resin. The method of preparation of said laminate infusion has many advantages, it is simple in design, economical and inexpensive, it can also manufacture plates (layered) large.

## MATERIALS AND METHODS

### Materials

The materials constituting the laminated polyester are a thermosetting resin (polyester) and reinforcing fiber woven jute.

In study the resin used is the thermosetting polyester resin type are older and cheaper. They are most common in the manufacture of composite parts and return in the manufacture of 95% of reinforced thermoset composites. During their manufacture, they are usually supplemented with 30% to 40 % solvent to separate the polymer chains meadow. This allows them to last long in a liquid state and stored for a period of time.

This is the time of its use as an accelerator is added and the catalyst in a well-determined sequence. They are often associated with the glass in the composite parts. It is generally composites at low cost (material cost of around 400-500 dinars per kilo. These resins are said unsaturated, ie that their molecular chains reveal double bonds may thereafter allow other assemblies. Polyester matrix composites are used primarily for consumer applications: Production of swimming pools, boats, tanks ...

Mover, a red jute used for prepared the composite laminate in this experimentation, has been. The jute is a plant of the tropics (genus *Corchorus*) belonging to the family Tiliaceae. The shaft reaches a height of 4 to 6 m with a diameter of about 3 cm. Jute grows mainly in Bangladesh which holds a virtual monopoly of its trade. There are two varieties (white and red), which requires a preliminary sorting before use. The ultimate fiber is very short and lignified. The extraction of the fiber is obtained by steeping and milling. After retting, disconnect the fiber is cleaned and hemp rinsed with water [5], [6].



Fig.1: From plant to jute fabric

### Tensile test

Tensile tests of samples of jute realised are on a universal machine Zwick of Z10/SN5A kind with a force sensor of 1 kN. It is controlled by computer (software testXpert V12.0). Specimens used for tensile on are sized in accordance with the AFNOR NF T 57-105 equivalent to the ASTM D 790-84a. The average dimensions of the specimens are given in Table 1. The tensile tests are performed on a universal machine Zwick Type 10 kN computer controlled (testXpert software V 9.0) with a test of 2 mm / min and equipped with a force sensor of 1 kN (Figure 4).

Table 1. Specimen dimensions (mm).

Total length L	length between the jaws l	Thickness h	Width b
250	150	0.87-0.97	50



Figure 2. Shows the geometry of the test pieces used



Figure 3. Tensile test of reinforcing jute fabric

### Laminates preparation

The preparation of laminate jute / polyester is formed by the vacuum method (Fig.4). the tissue is prepared and already cut to size 300x300mm.

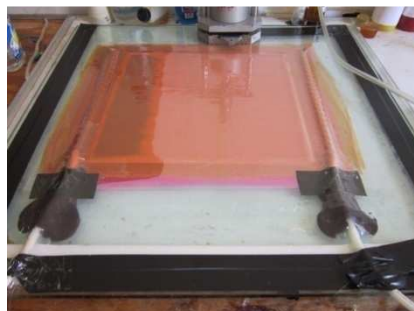
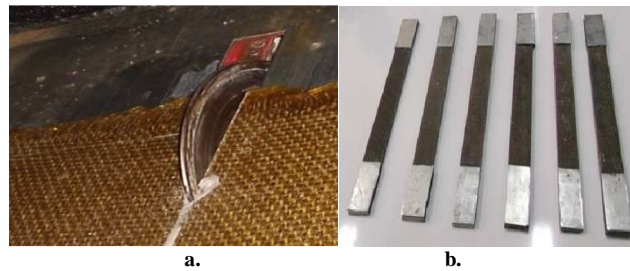


Fig.4. plate prepared for the press

The plates obtained, 300 x300 mm, are dried in an oven at 80 ° C for 4 hours. The specimens are cut according to the AFNOR NF T 57-105 for the mechanical tests. The plates are cut with a diamond chainsaw lubricated disk. [17]. [18]. [19].



**Figure 5.**  
a. for cutting a wafer laminate  
b. Laminated composite samples (Jute / polyester).

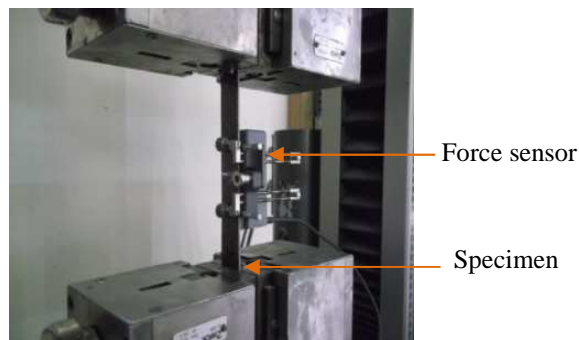
The average dimensions of the specimens are given in Table 2.

**Table 2. Specimen dimensions (mm).**

jute	total length	Length between tool	width	Thickness
strain	250 ± 1	150 ± 1	25 ± 0,5	2-4

#### Tensile tests of laminates

For the identification of mechanical properties of laminated jute / polyester (Young's modulus, maximum stress and failure stress), tensile tests are carried out according to EN ISO 527-5. Tensile tests are performed on specimens of dimensions 50 x 250 x 2.5 mm provided with heels on the same universal machine Zwick of Z10/SN5A such as before.



**Figure 6. Tensile test**

#### Fatigue behavior study .

The fatigue behavior of a material is usually defined by the relationship between the loading level and the number of applied load cycles causing failure of the material.

Fatigue tests on samples [0 / 90 ] 4 are carried out on a Zwick machine types vibrophore (Fig.7 ) .The fatigue tests are controlled by load at a frequency of 30 Hz and a ratio  $R = 0.5$ . All fatigue tests were conducted at room temperature [12] , the samples have undergone different levels of loading relative to the maximum load traction : 50%, 55 %, 60 %, 70 % and 80%. For each load level , a minimum of three test specimens was tested.



Figure 7: Fatigue testing of the laminate

## RESULTS AND DISCUSSION

### tensile properties of jute

the tensile properties of jute are shown in table 3 and illustrated in figure 8,9,10

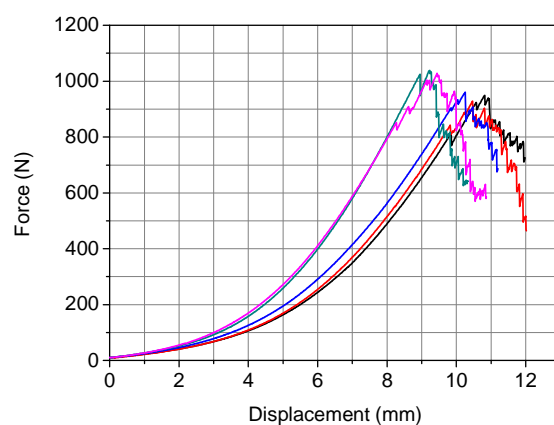


Figure 8: Evolution of the force versus displacement for fiber jute 0 °

Table 3. Average values of maximum strength, modulus of elasticity and deformation

jute	F max (N)	E (MPa)	$\epsilon$ (%)
Valeur moyenne	958.68	32	8.39

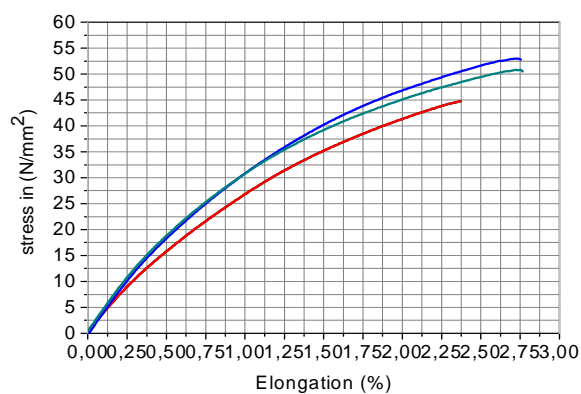


Figure 09.strain laminated

The curves obtained show a variation strength elongation takes place in three stages: linear and nonlinear through maximum strength followed by a slight decrease in strength and finally obtained a total break and following a very rapid fall in the latter .

Figure (fig.09) below shows the evolution of the stress versus longitudinal strain for laminated jute / polyester, which shows a small fluctuation between different specimens reflecting the homogeneity of the material developed. We find that the stress varies linearly (elastic zone) to a value of around 3885 MPa with an elongation of 2.08%

Figure 10 illustrates changes in the shear stress as a function of the deformation of a laminated jute / polyester [+45 ° / -45 °] 4. Nonlinear behavior beyond curve there.

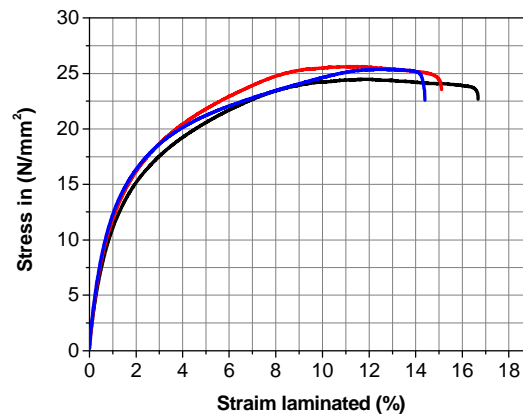


Figure 10: Tensile test on jute / polyester [+45 / -45] 4

The mechanical properties of laminated composite jute / polyester are summarized in Table (tensile loading):

Table 4. Stratified medium mechanical features developed

E [MPa]	$\sigma_{max}$ [MPa]	$\epsilon_{max}$ [%]	$\sigma_{rup}$ [MPa]	$\epsilon_{rup}$ [%]
32	47	2.08	3500	2.50

It is observed that the tensile curves consist of two linear portions . The Young's modulus is calculated on the first part of the response .However, the second represents the linear behavior until rupture. A clear break is observed in tension [35].

This study of the static behavior of these materials continues with a study of the fatigue behavior.

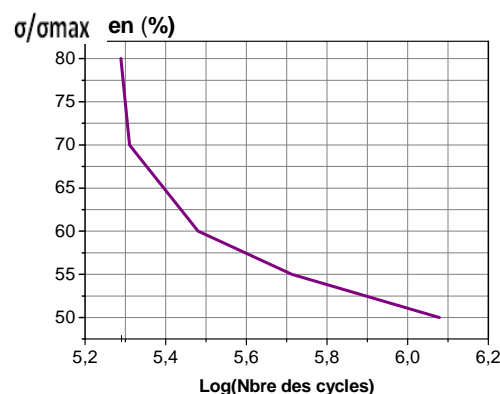


Figure 11 : la courbe de Wöhler de stratifié jute/polyester



### Operating fatigue tests

Initial results have allowed the construction of the Wöhler curve for our materials (ratio of maximum stresses as a function of number of cycles to failure) (Fig. 11). It is noted that in the test pieces do not break under a charge level equal to 50 %. No delamination was observed during fatigue testing.

during fatigue testing was also observed an increase in temperature of samples from May to July °C remains in the ISO 13003 standard, which requires a temperature increase of less than 10 °C.

In the case of the curve Wohler there is an increase in the number of cycles to failure when  $\sigma/\sigma_{\max}$  decreases. Optionally, below a certain threshold rupture 'evitee'. For usual industrial applications, to defines the limit of fatigue as stress amplitude below which the rupture has not place for  $N = 10^6$ . For a stress level as the rupture does not occur for  $N = 10^6$ , however there may be a break for a larger number of cycles (up to a  $10^9$ ).

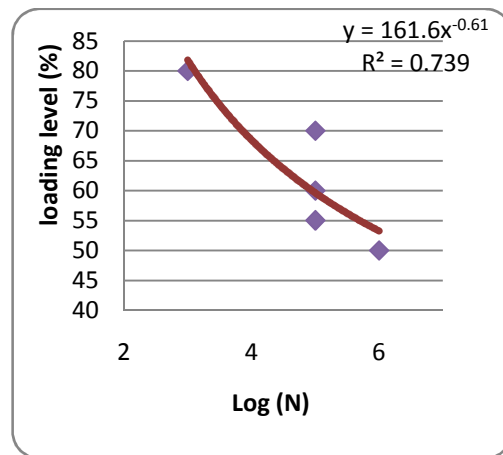


Figure 12: Wohler curve of laminated jute / polyester

### CONCLUSION

In this study, quasi-static and fatigue behavior of composite laminates jute / polyester [0 / 90] 4S are characterized at ambient temperature. tensile behavior is bilinear and the main mode of failure is out of reinforcements.

The tensile tests on the laminate jute / polyester showed a similar behavior on two levels : a linear portion up to 20 MPa and a nonlinear portion to rupture stress max of 47 MPa, followed by elongation of 2.08 %. with a break elongation of 2.50 %

increasing the temperature of the test pieces ( 5 to 6 °C ) when the fatigue test remains in the ISO 13003 standard, which requires a temperature increase of less than 10 °C.

A clear break of the laminate tensile were observed. There is also the effect of loading level on the number of cycles because it is noticed that a change in number of cycles depending on the load level threshold, the level decreases more and more as load increases the number of cycles.

in the end we can say that there is no predetermined rule valid for any composite. Fatigue of composite material depends upon the nature of the fibers and resins, of the quality of the interfaces. Many parameters that can be optimized in order to better respond to the proposed and improve resistance to fatigue application.

### REFERENCES

- [1] Duigou A, Davies P, Baley C. *Composites Science and Technology*. Vol. 70, p. 231-239, **2010**.
- [2] Wambua P, Ivens J, Verpoest I. *Composites Science and Technology*; Vol. 63, pp. 1259-1264, **2003**.
- [3] The Duigou, I Pillin, A Bourmaud, P Davies, C Baley. *Composites : Part A*. Vol. 39, pp. 1471-1478, **2008**. Comptes rendings of JNC 17 - Poitiers **2011**
- [4] Mir A, R ZITOUNE, F COLLOMBET, B BEZZAZI. *Journal of Reinforced Plastics and Composites*. Comptes Rendus des JNC 16 ¾ Toulouse **2009**
- [5] Baley C. (**2002**): *Composites* 33A, 939-948.

- [6] Spatz H.CH., Köhler L. et Niklas K.J. (1999). *The Journal of Experimental Biology*, 202, p. 3269-3272.
- [7] Köhler L. et Spatz H.C. (2002). *Planta*, 215,p. 33-40.
- [11] Broutman L. J. , Sahu S. (1972). *Composites Materials, testing and design*, ASTM STP , pp. 170-188,.
- [8] Kawabata S., Niwa M., and Kawai H. (1973). *J. Textile Inst.*, 64, 1, p. 21-46.
- [9] Chaudhuri K., Chaudhuri M.A. (1998) *Biologia plantarum* 40 (3) 373-380.
- [10]Hearle J.W.S. (1963). *Journal of Applied Polymers Science*, 7, p. 1207-1223.
- [11]Rao, R. M. V. G. K., Balasubramaniam, N. And Chanda, Manas, (1981). *J. App. Poly. Sci. Engg*, 26, p. 9069
- [14]Garkhail, S.K., Heijenrath, R.W.H, T. Peijs (2000). *Appl. Compos. Mater.* 7, 351–372.
- [16]Ray D, Sarkar BK, Das S, Rana AK. (2002).. *Compos Sci Technol*; 62:911–7.
- [17]Khan MA, Mina F, Drzal LT. (2000). *3rd international wood and natural fibre composite symposium*, September; [in Kassel].
- [18]Gassan J, Bledzki AK. (1999. *Polym Comp*; 20(4): 604–11.
- [19]Park J.-M., Kim P. G., Jang J. H., Wang Z., Hwang B.S., DeVries K. L. (2008).. *Composites Part B* 39 1042-1061.
- [20]Khan MA, Rahman MM, Akhunzada KS. (2002). *Grafting. Polym Plast Tech Eng*; 41(4):677–89.
- [21]Masudul Hassan M, Islam MR, Khan MA. (2003). *J Adhes Sci Technol*; 17(5):737–50.
- [22]Khan M. A., Haque N. , Al-Kafi A , Alam M. N. , Abedin M. Z. (2006). *Polymer-plastics technology and engineering* ISSN 0360-2559 CODEN PPTEC7 , vol. 45, no4-6, pp. 607-613.
- [23]Raj R. G., Kokta B. V. and Daneault C.. (1990). *Journal of Materials Science*, 25, 1851-1855.
- [24]Harper D. and Wolcott M., (2004). *Composites Part A: Applied Science and Manufacturing*, 35(3), , 385-394.
- [25]Aranberri-Askargorta I., Lampke T. and Bismarck A., (2003) *Journal of Colloid and Interface Science*, 263 (2), 580-589.
- [26]Ajay Karmarkar, S.S. Chauhan, Jayant M. Modak and Manas Chanda (2007), *Composites Part A: Applied Science and Manufacturing*, , 38 (2), 227-233.
- [27]Naik J. B.; Mishra S.. (2007). *Polymer-Plastics Technology and engineering* 46(5), 537 – 540.
- [28]Sy Trek Sean, (2007). *Polymer-Plastics Technology and engineering*, 46(4), 421 – 425.
- [29]Keener T. J., Stuart R. K. and Brown T. K., (2004). *Composites Part A: Applied Science and Manufacturing*, , 35 (3), 357-363.
- [30]Jiang H., Kamdem D. P.. (2004). *A literature review Journal of Vinyl and Additive Technology*, 10 (2), 59-69.
- [31]Sabeel K A., Vijayarangan S. (2008). *Journal of materials processing technology* 207 pp.330-335.
- [32]Sabeel K.A, Vijayarangan S.and Rajput C., *Journal of reinforced plastics and composites. In press*
- [33]Alvarez V., Rodriguez E.and Vázquez A.. (2006). *Thermal. Journal of Thermal Analysis and Calorimetry*, Vol. 85 2, 383–389.
- [34]Silva FA , Chawla N , RDT Filho . "Materials Science and Engineering A. Vol. 516, pp . 90-95 , 2009.
- [35]C. Belkacemi . Mémoire de Magistère, Boumerdes 2007. Algerie