Paper ID: MS-03

Fabrication and Experimental Investigation on the Effect of Transverse Orientation of Jute Fiber Reinforced Epoxy Composites and Hybrids

Md. Gausul Amin [1, a], Md. Abrar Atik [1, b], Khurshida Rakhi [1, c],
K. M. Asad Habib [1, d], Md. Shafiul Ferdous [2, e]*

[1] *School of Mechanical Engineering, Bangladesh Army University of Science and Technology, Saidpur-5310, Bangladesh*

[2] *Department of Mechanical Engineering, Khulna University of Engineering & Technology, Khulna-9203, Bangladesh*

[a] *gausulaminsaikat@gmail.com,* [b] *abraratik@gmail.com,* [c] *rakhime048@gmail.com,*
[d] *rafisalmankhan222@gmail.com,* *[e] *munazeer_218@yahoo.com*

Abstract

The interest of natural fiber composites has increased dramatically due to its light weight, cheaper, moderate mechanical property and most importantly biodegradable or environment friendly quality. The advancement of innovative materials using natural fibers is on the anvil and are growing day by day. Few researchers fabricated jute fiber composites using twill type jute fiber cloth by jute yarn. In this study, a hand loom was developed to prepare a special types of unidirectional jute fiber woven cloth. Hand lay-up process was applied to fabricate the composites and hybrids. Then a series of tests were carried out to investigate the effect of the transverse orientation on the mechanical properties of the fabricated composites. Hybrids composites were also introduced by incorporating aluminum foil to get the elevated mechanical properties. Improved mechanical properties were found when woven cloths were in alternating direction during composites fabrication, and in the case of hybrids composites.

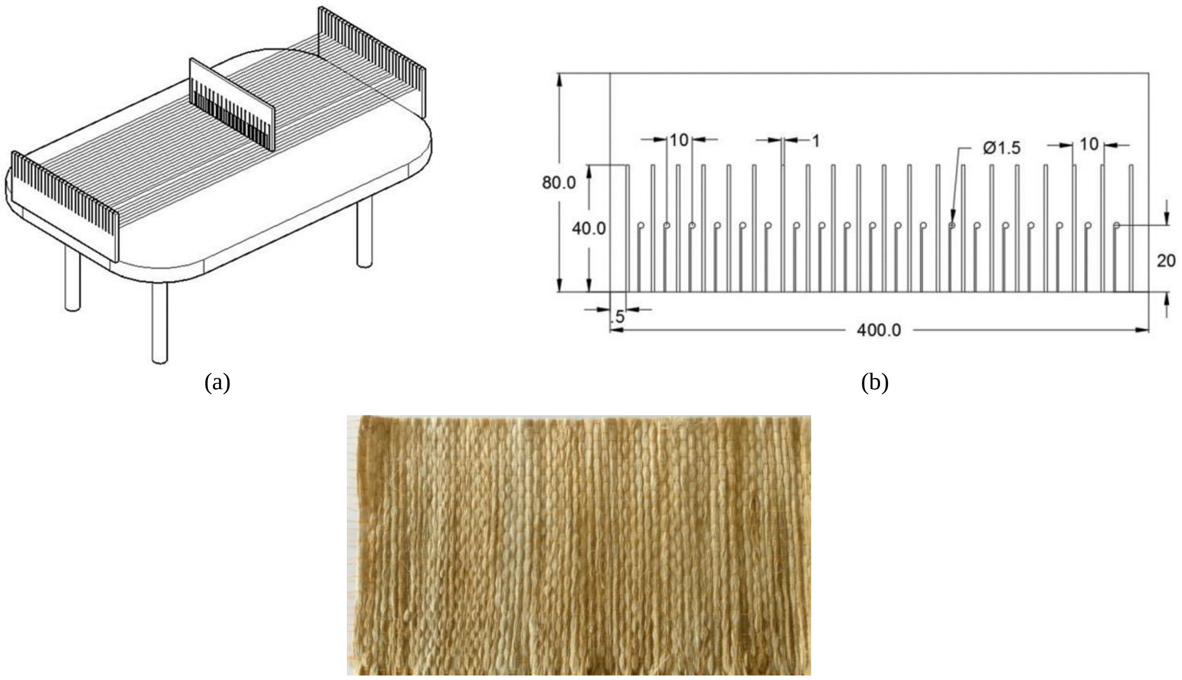
Keywords: Hand loom, Natural fiber composites, Woven fiber mat, Transverse orientation.

1. Introduction

During the last two decades, composites material playing an important roles in various engineering sectors. Therefore, researchers are trying to emphasis more on composites materials [1-7]. Jute is a natural fiber and plenty in Bangladesh with a comparatively very cheaper rate than any fiber in the world which is biodegradable and enhanced mechanical properties. However, as jute fiber contains cellulose in it, so it has hydrophilic properties. If this hydrophilic properties could be controlled then jute fiber reinforced composites could be a wonderful materials for the outdoor engineering structures. The orientations of fiber has an impacts on mechanical properties of fabricated composites [1, 3]. Therefore, the effect of transverse orientation of woven jute fiber mats were taken into consideration for this study. Manual hand loom was introduced to weave the jute fiber mats, and hand lay-up with cold press process was applied to fabricate the composites and hybrids.

2. Fabrication Procedure

First of all, a wooden frame was constructed for fabrication. A polyethylene sheet was layered on the frame to avoid direct contact with wooden frame. Then epoxy resin and hardener were mixed at a ratio of 12:1. Resin and hardener mixture was poured onto the polyethylene sheet. With the help of a roller, resin and hardener mixer was applied evenly on the sheet. After that woven jute mats were laid on the surface of the mixture and another layer of resin and hardener mixture was applied on top of the woven jute mats with the help of a roller. Other layer of jute mats and aluminium foil were set following the same way. Finally, a heavy surface plate was pressed on the layered mats and let it stay for 24 hours to set the resin and hardener with jute mats and aluminium foil in case of hybrid. For 1 square centimeter composite, 0.58 gm of resin-hardener mixture is required.



(a) (b)

(c)

Fig. 1: (a) Hand Loom (b) Dimension of Hand Loom Comb (c) Completed Jute fiber clothe

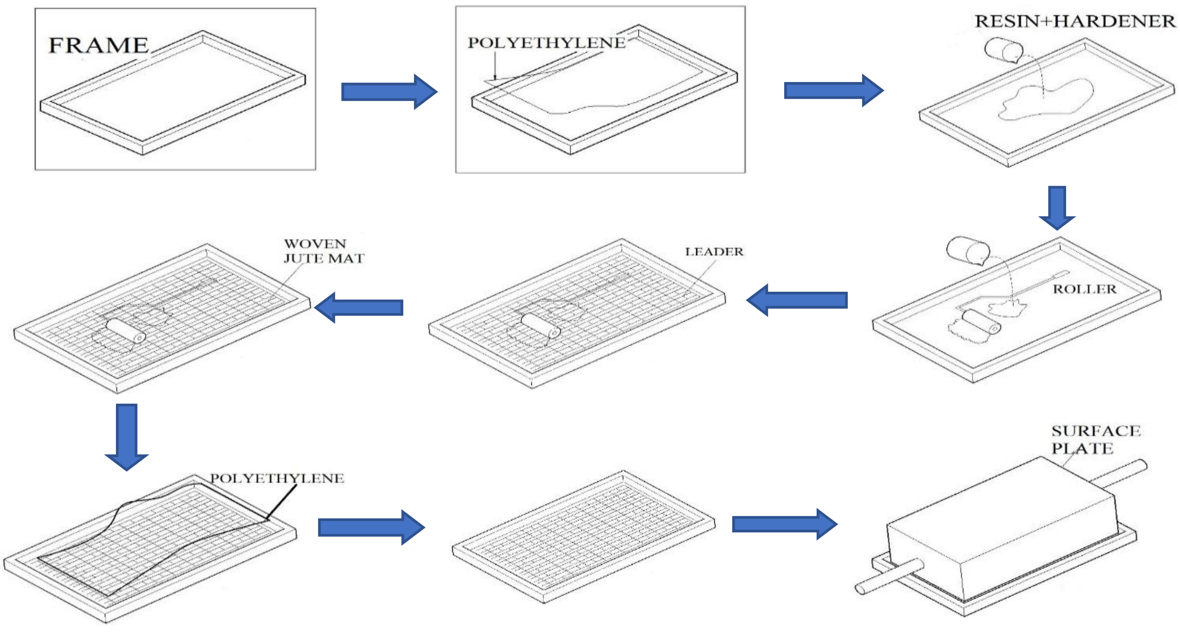


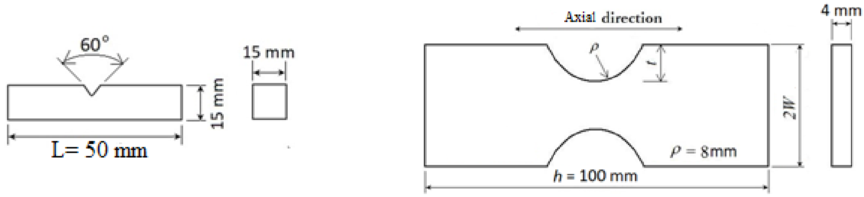
Fig. 2: Schematic representation of the fabrication process of epoxy Jute composites.

Table1: Arrangement of different formation of Jute and Aliminium composite

Note: "*A*": Aluminum foil; horizontal and vertical lines indicate horizontal and vertical orientation of jute fiber in woven mat.

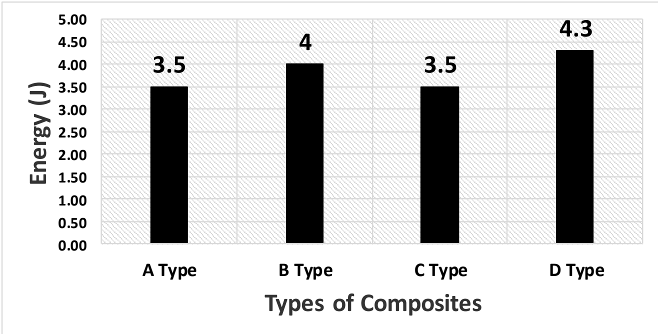
Type of Composites	Arrangement of materials	Type of Composites	Arrangement of materials
Type *A*	| + | + | + | + |	Type *B*	| + — + | + — + |
Type *C*	| + A + | + A + | + A + | + A + |	Type *D*	| + A + — + A + | + A + — + A + |

3. Experimental Result and Discussion

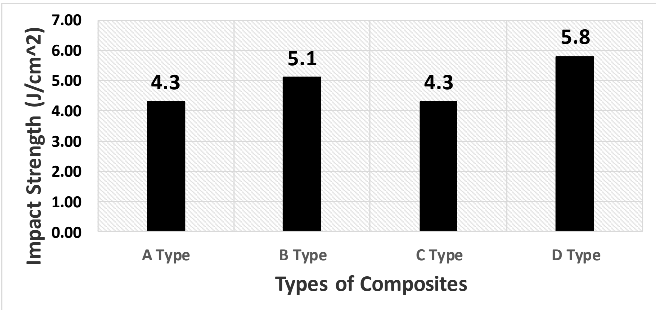


(a) (b)

Fig. 3: Specimen Geometry of fabricated epoxy composites: (a) Izod Impact test, (b) Tensile test



(a)



(b)

Fig. 4: Result of Impact test (a) Energy (b) Impact Strength

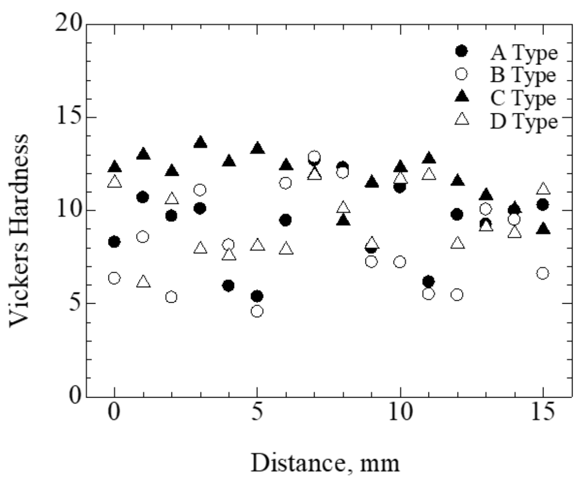


Fig. 5: Result of Vickers Hardness Test

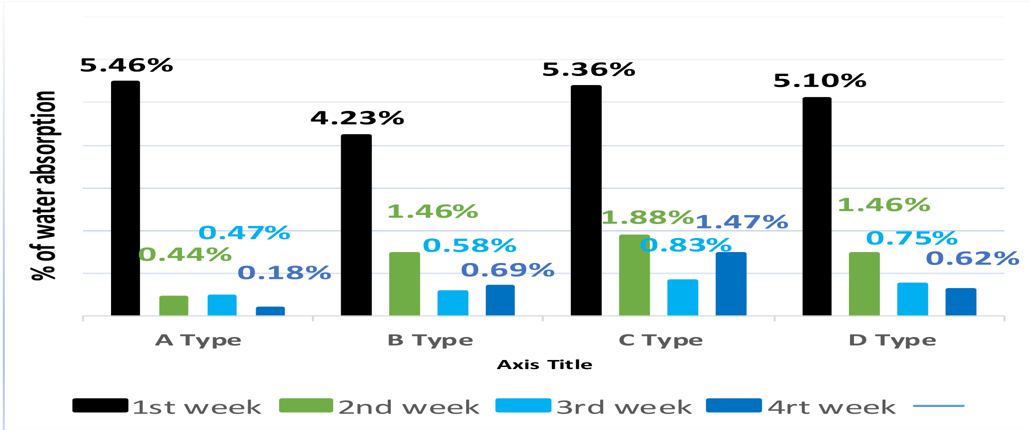


Fig. 6: Percentage of water absorption of various types of fabricated composites

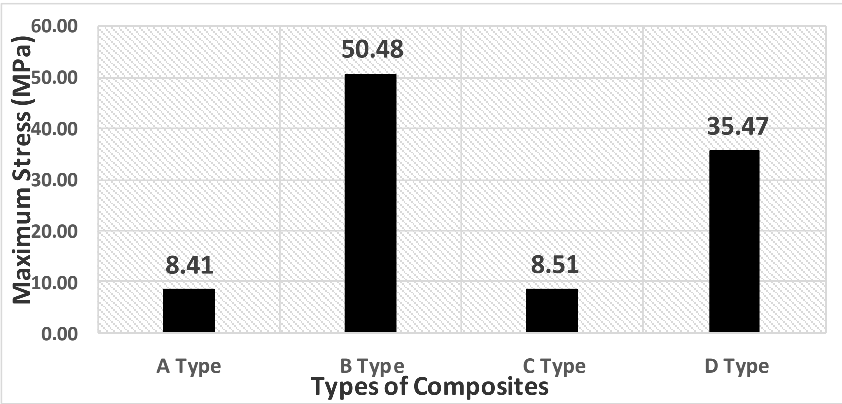


Fig. 7: Result of Tensile test

Impact Strength: Different types of jute composites and hybrid materials are tested in universal impact test machine. The specimen dimension is shown in figure 3(a). There is a notch of 2mm depth and 45° angle. From figure 4(a) it can be seen that type *D* has considerably highest impact energy. Also, type *B* has impact energy close to *D*. Alternative direction of fiber leads to this high impact energy. Again, type *A* and *C* has low impact energy, due to transverse alignment of fibers. From figure 4(b) it can be seen that type *D* has considerably highest impact strength of 5.8J/cm^2. Also type *B* has impact energy of 5.1 J/cm^2 close to *D*. Alternative direction of fiber leads to this high impact strength. Again, type *A* and *C* has low impact energy of 4.3 J/cm^2 due to transverse alignment of fibers. From the summation of the above-mentioned results it can be seen that type *D*, which is the composition of 11 layers of jute and 10 layers of aluminum foil in alternate direction has the highest impact energy and strength. Again, type A_{11}, which is the composition of 11 layers of jute in transverse direction has the lowest impact energy and strength. These results are due to the jute fiber orientation. Alternate direction jute fibers show high impact strength and energy, when transverse direction has lower impact energy and strength.

Vickers Hardness: Hardness was measured by Vickers hardness tester. From the graphical representation of figure 5 we can see that type *C* which is the composite of 5 layers of jute in transverse direction, and 4 layers of aluminum foil has the maximum hardness. Minimum hardness is shown by type *B* which is the composite of 5 layers of jute in alternate direction. This variation in hardness is due to the voids. These voids could be eliminated by improving the fabrication process.

Water Absorption Test: The percentages water absorption was measured by the following equations.

$$W_{A}(t)= \frac{Wn-Wo}{Wo} \times 100 \quad \text{..........} \quad (1)$$

From the graphical representation (Figure 6) we can see that all types of composites have consumed water. Among these most hydrophilic is type *D* which is composed of 5 layers of jute fiber mat in alternating direction with loading direction, and 4 layers of aluminium foil. The less water is consumed by composite of 5 layers of jute in alternative direction (type *B*). If this problem can be solved, this composite would be perfect for exterior using. Type *D* has absorbed approximately 0.7896 gm in 5 weeks. Again, Type *B* has consumed minimum water, approximately 0.5751 gm in 5 weeks. The rate of water consumption varies due to the abundant or open fiber yarns.

Tensile Strength: From figure 7, it can be seen that type *B* has considerably highest capability to withstand tensile stress of 50.48GPa. Also type *D* has capability to withstand tensile stress of 35.48GPa which is closer to type *B*. Alternative direction of fiber leads to this high capability to withstand tensile stress. Again, type *A* and *C* has low capability to withstand tensile stress of 8.41GPa and 8.51GPa, due to transverse alignment of fibers. From the results it can be seen that type *B*, which is in the alternate direction of woven jute fiber mats has the maximum capability to withstand tensile stress. Again, type *A* which is fabricated in the transverse direction of all jute fiber mat has the minimum capability to withstand tensile stress. These results are due to the fiber directions. Either transverse or alternative. Alternate direction fibers show high capability to withstand tensile stress, and transverse direction composites have lower capability to withstand tensile stress.

Microstructure by SEM:

Fig. 8-10 show the micrograph of fabricated composites and hybrids by *SEM*. The voids found in the composite, and these voids are formed due to lack of applied pressure during fabrication process. By improving the hand-layup method and by using Vacuum Resin Infusion system these voids could be eliminated. The fiber yarns splattered for unfinished boundaries. Fiber imprints are also found. The vertical and horizontal fiber imprints are due to the alternative direction of the fiber layers.

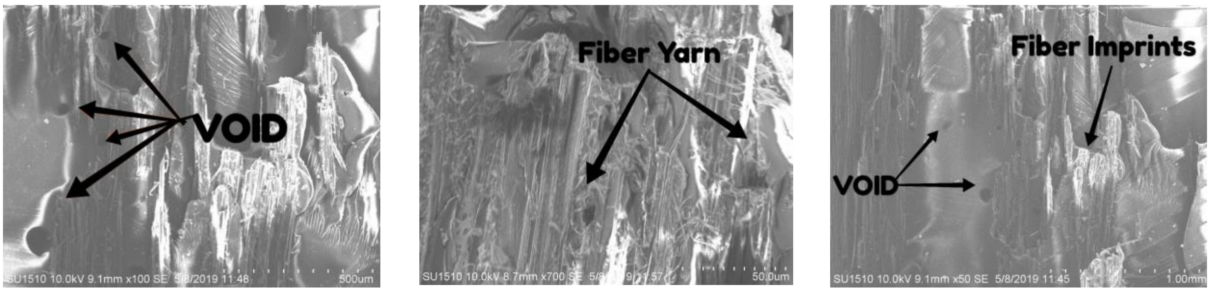


Fig. 8: Micrograph of *A* type specimen by *SEM*

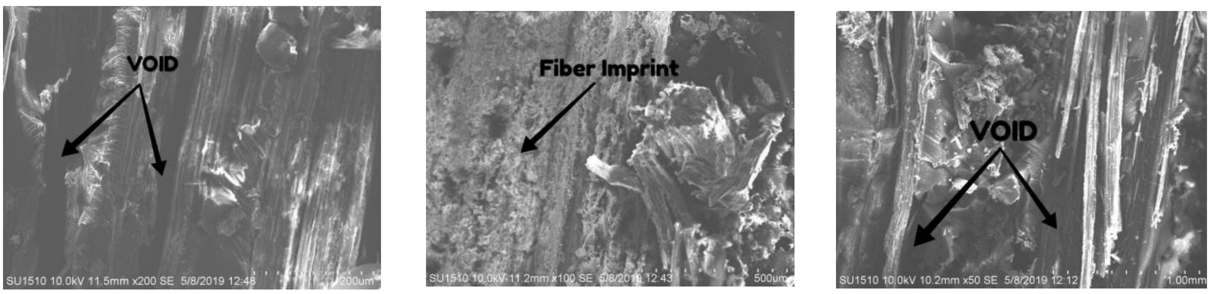


Fig. 9: Micrograph of *B* type specimen by *SEM*

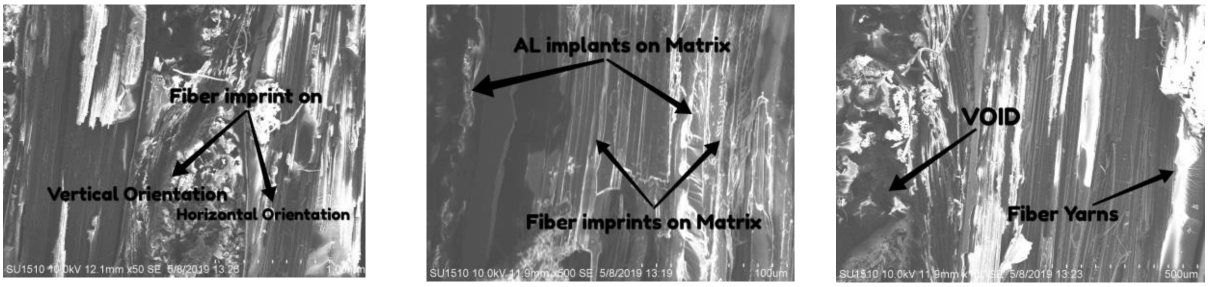


Fig.10: Micrograph of *D* type specimen by *SEM*

4. Conclusion

After performing the tests, the results were analyzed. The following physical properties are found:

(1). From the water absorption test, it can be determined that composition of jute with aluminium foil in alternative direction (Type *D*) is the most hydrophilic and absorbed maximum amount of water approximately 0.7896gm in 5 weeks. Again, Type *B* has consumed minimum water, approximately 0.5751gm in 5 weeks. As the water absorption percentage is quite high, if the presentence could be taken down a bit, it would become perfectly suitable for outdoor usage.

(2) Impact Strength is highest when aluminium foil is incorporate with alternative direction jute fiber mat (Type *D*) at 5.8 J/cm^2. This impact tolerance is improved due to the enhanced mechanical properties of aluminium foil which is incorporated with woven jute fiber mat. Also, the alternate direction is helpful to distribute forces of impact.

(3) Maximum tensile stress was observed in the case of *B* type specimen. The tensile stress is 50.74 MPa due to the alternative direction. In axial direction, jute fiber composite shows maximum tensile strength than that of other directions.

(4) Maximum hardness was found in the case of *D* type specimen, where aluminum foil was incorporated with the woven jute fiber mat, and it was found *HV*=14.8. The hardness was scattered. The result could be improved by the modification of the composites fabrication process.

(5) The voids found in the composite which can be observed by the micrograph of *SEM*. By using Vacuum Resin Infusion system these voids could be eliminated.

Reference

[1]. T. M. Aranno, S. Mia, M. S. U. Khan, M. A. M. Hasan, N. S. Supto, A. S. Sujon, A. B. Rashid, M. S. Ferdous, Fabrication, Experimental Investigation of Jute Fiber Reinforced Epoxy Composites and Hybrid Composites, ICKEM 2019, March 29-April 1 2019, Oxford University, UK.

[2]. D. N. Saheb, J. P. Jog, Natural fiber polymer composites: A review, Adv. in Polym. Tech. 18 (1999) 351–363.

[3]. M. S. Ferdous, S. M. M. Rahman, C. Makabe, Effect of Fiber Direction and Stress Ratio on Fatigue Property in Carbon Fiber Reinforced Epoxy Composites, ICDMM2018. 11-13 August (2018) Okinawa, Japan.

[4]. C. Makabe, M. Fujikawa, M. S. Ferdous, S. A. Setyabudi, Fatigue Strength of Notch Specimen of Machineable C/C Composites, J. of High Pr. Ins. of Japan. 51 (2013) 7-15.

[5]. A. K. Bledzki, J. Gassan, Composites reinforced with cellulose based fibers, Prog. in Polym. Sci. 24 (1999) 221–274.

[6]. S. J. Eichhorn, C. A. Baillie, N. Zafeiropoulos, L. Y. Mwaikambo, M. P. Ansell, A. Dufresne, K. M. Entwistle, P. J. Herrera-Franco, G. C. Escamilla, L. Groom, M. Hughes, C. Hill, T. G. Rials, P. M. Wild, Current international research into cellulosic fibres and composites, J. of Mat. Sci. 36 (2001) 2107–2131.

[7]. I. A. T. Razera and E. Frollini, Composites Based on Jute Fibers and Phenolic Matrices: Properties of Fibers and Composites, J. of A. Polym. Sci. 91 (2004) 1077-1085.