International Conference on Mechanical, Industrial and Materials Engineering 2017 (ICMIME2017)
28-30 December, 2017, RUET, Rajshahi, Bangladesh.

Paper ID: MS-193

Synthesis and Experimental Investigation of PALF Twill Fabric Reinforced Polyester Biocomposites

*Subrata Chandra Das[1], Debasree Paul[2], Md. Abdullah Al Mamun[3], Bidhan Kumer Mitro[3], M. Tauhidul Islam[2], Mubarak Ahmad Khan[4]

[1]Pabna Textile Engineering College, Pabna-6600, Department of Textiles, Ministry of Textiles and Jute, Bangladesh
[2]Department of Textile Engineering, Khwaja Yunus Ali University, Sirajgonj-6751, Bangladesh
[3]Department of Textile Engineering, Mawlana Bhashani Science and Technology, Tangail-1920, Bangladesh
[4]Atomic Energy Research Establishment, Bangladesh Atomic Energy Commission, Dhaka, Bangladesh
Email: sc.das_mbstu@yahoo.com

Abstract

In this research work, the effect of fiber content by weight% on the mechanical properties of woven pineapple leaf fiber (PALF) fabric (1×1 twill weave) reinforced polyester biocomposites has been investigated experimentally. The composites are fabricated by hand lay-up technique in a mold, a dead weight of 15 kg is applied for better curing and then kept it at room temperature for 24 hours. Among all the resulting composites, the composite with 25% fiber content (by weight) demonstrates improved mechanical properties, such as tensile strength (TS), bending strength (BS), tensile modulus (TM), bending modulus (BM), and impact strength (IS) are found to be 29.96, 28.14, 57.05, 17.00 and 32.28% respectively. However, elongation at break is decreased 50.07%. It is revealed that mechanical properties of the composites increase with the increase of PALF weight% in the composites.

Keywords: PALF, twill fabric, biocomposites, polyester resin.

1. Introduction

Fiber reinforced polymer matrix composites are one of the future materials replacing the traditional materials in the field of plastic, automobile, construction, aerospace, military industries and so on. In future most of the materials are seemed to be fiber based which will be promising and a revolutionary step. Fibers from natural origin are gained priority due to its some unique advantages such as availability, low cost and biodegradability. Moreover, the natural fibers are environmental friendly and ease of processability with a wide range of matrix materials [1-6].

PALF possesses some attractive mechanical properties among various natural leaf fibers. These fibers are multicellular and lignocellulosic. They are extracted from the leaves of the plant *Ananus Cosomus* belonging to the Bromeliaceae family by retting. The main chemical compositions of PALF are cellulose (70-80%), lignin (5-12%) and ash (1.1%) [7]. Compared to other natural fibers, PALF exhibits superior mechanical properties due to its high cellulose content (around 70-82%) and low microfibrillar angle (14°) [8-11].

Many experiments have already been accomplished with PALF composites [12- 22]. Das et al. reported the PALF plain fabric based polyester composite and evaluated their mechanical properties from 15 to 25% fiber loading [12]. Kaewpiron et al. and Smitthipong et al. produced green composites by incorporating PALF and PLA [13, 14]. Kottaisamy et al. reported on the development of PALF reinforced plastic composites [15] and effect of fiber length examined by Chattopadhyay et al. [16, 17], and thermoplastic materials such as low density polyethylene (LDPE), high density polyethylene (HDPE), polypropylene (PP) and starch/poly(lactic acid) (PLA) were also incorporated with PALF [14, 18-22]. The polyester matrix has also wide range of applications with various natural and synthetic fibers [23-29]. The aim of the present study is to fabricate the PALF twill fabric based polyester biocomposites with fiber loading by weight (%). Then the various mechanical properties of the composites are evaluated.

2. Experimental

2.1 Materials

The raw PALF is collected from the local market of Bangladesh. Unsaturated polyester resin and Methyl ethyl ketone peroxide (MEKP) also collected from SHCP, Singapore.

2.2 Methods

2.2.1 Fabrication of composites

The fiber is extracted from pineapple leaf and yarn is produced by hand twisting machine and then twill weave fabrics (1×1) are manufactured by handloom. The PALF twill fabric has 10 ends per inch (EPI) and 8 picks per inch (PPI). For composite fabrication, at first, PALF fabrics of twill weave structure (1×1) are cut into the desired size. The matrix material is prepared by mixing unsaturated polyester resin and 2% MEKP, mixed thoroughly before applying in the fiber. The composites are prepared by simple hand lay-up method and then placed it with the aluminum dices, a dead weight of 15 kg is loaded on the lay for 4 hours for better curing and adhesion between fiber and polyester matrix, and then kept it at room temperature for 24 hours. Three composites are prepared with 15%, 20% and 25% PALF content by weight with polyester resin.

2.2.2 Mechanical testing of the composites

2.2.2.1 Tensile test

Tensile tests are conducted according to ASTM Designation: D638-03 using a Universal Testing Machine (Model: H50KS-0404, Hounsfield Series S, UK) with a cross-head speed of 10mm/min at a span distance of 50 mm. The dimension of the test specimen is 120mm×15mm.

2.2.2.2 Flexural test

Static flexural tests are carried out according to ISO 14125 methods using the same testing machine mentioned above with a cross-head speed of 60mm/sec at a span distance of 25mm. The dimension of the test specimen is 60mm×15mm.

2.2.2.3 Impact test

Impact tests are conducted on unnotched mode composite specimens according to ASTM D 6110-97 using a Universal Impact Tester (HUNG TA INSTRUMENT CO. LTD, Taiwan), hammer mass of 2.63kg, gravity distance of 30.68 mm and lift angle of 150º.

3. Result and discussion

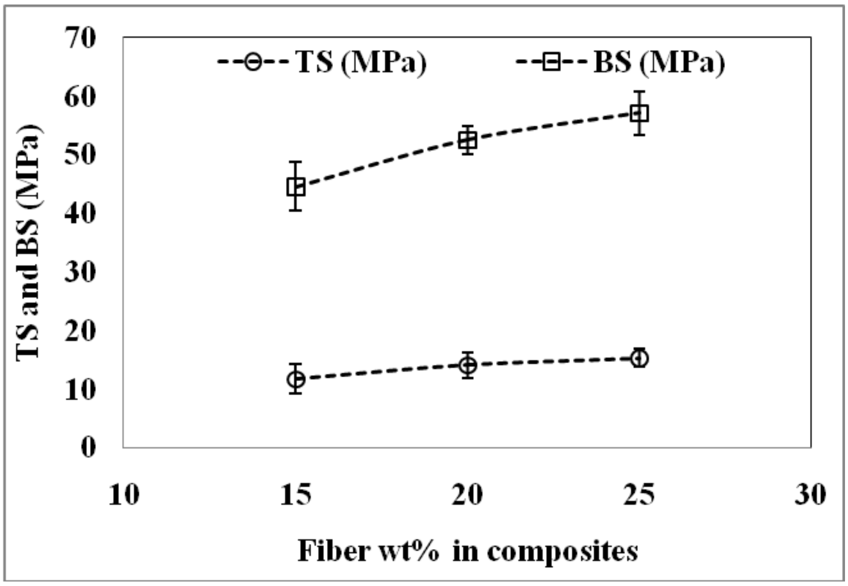

Fig. 1. Effect of PALF wt% on the TS and BS of the composites

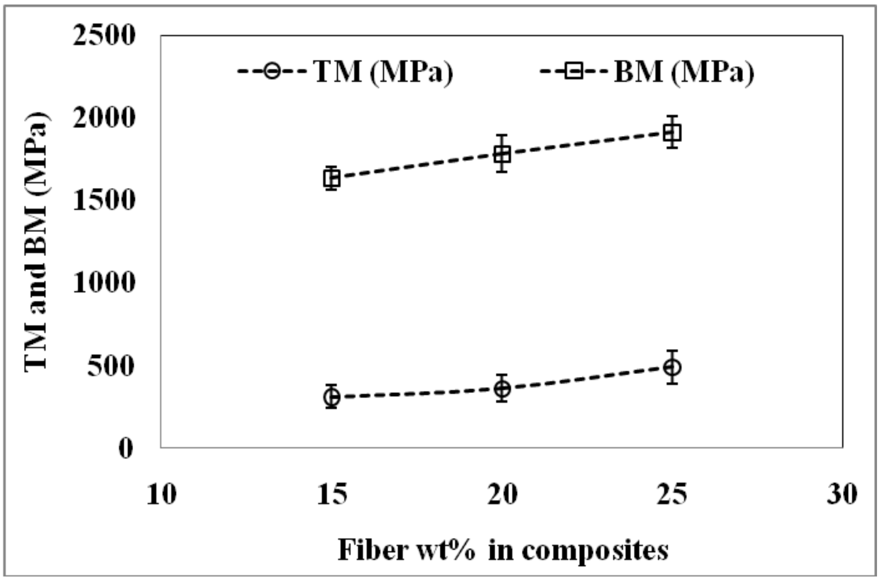

Fig. 2. Effect of PALF wt% on the TM and BM of the composites

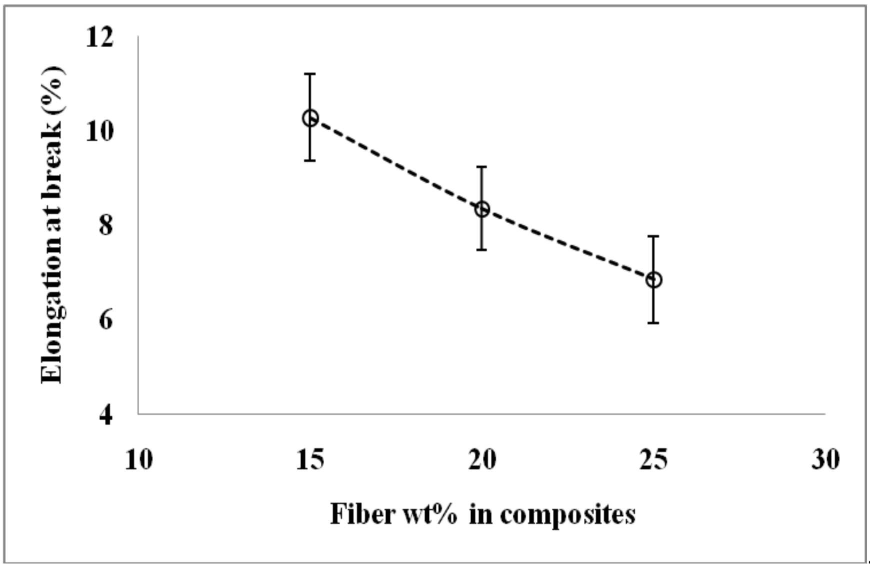

Fig. 3. Effect of PALF wt% on the elongation at break of the composites

Effect of PLAF fiber content on the mechanical properties of twill fabric reinforced polyester composite is measured and the results are presented in Fig. 1, 2, 3 and 4. The TS and BS of the composites are found to increase on increasing the percentage of PLAF content in the composites. The higher TS and the BS at 25% fiber content are found to be 15.27 and 57.10 MPa respectively. The TM and BM of the composites also followed the same way like TS and BS, and the effect of fiber content on elongation at break (%) of the composite is shown in Fig. 3. The highest TM and BM of the composites (25% fiber content) are found to be 490 and 1913 MPa respectively (Fig. 2). Here, our experiment is limited to only 25% fiber content by weight. The highest values of mechanical properties exhibited by 25% fiber content composite may be explained in terms of orientation and homogeneity of fibers within the matrix. At this stage, fibers get maximum level of orientation and mixed homogeneously within the matrix. When the load is applied, stress is uniformly distributed among the fibers. As a result, mechanical properties of the composites achieve maximum values. At low fiber content, poor fiber population causes low load transfer capacity among the fibers. As a result, accumulation of stress occurs at certain points of the composite and strains are also found highly localized in the matrix [30]. This contributes poor mechanical properties of the composites at low fiber content. Moreover, mechanical properties value increases in twill weave composite due to more compactness and more cover factor.

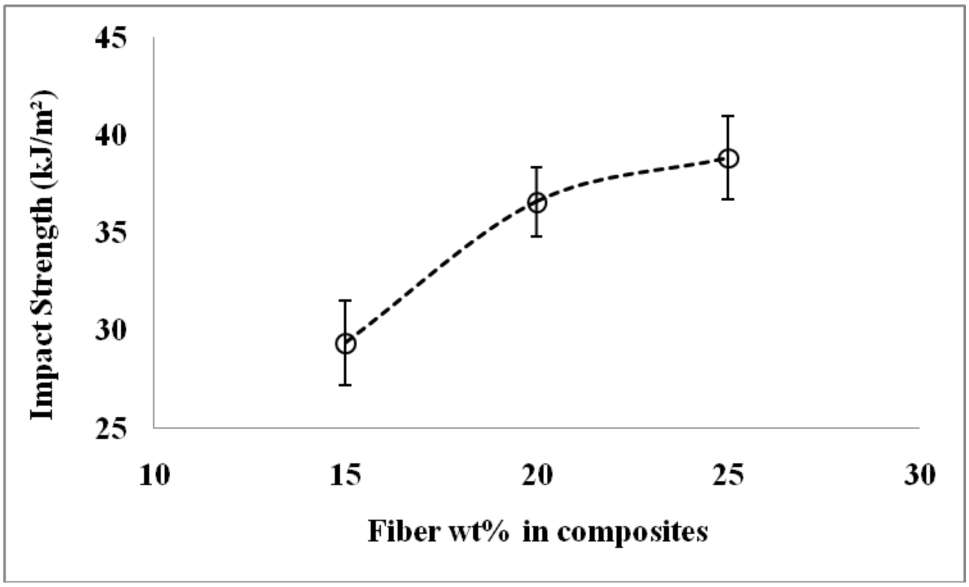

Fig. 4. Effect of PALF wt% on the IS of the composites

From Fig. 4, it is found that the impact strength (IS) of the twill fabrics reinforced polyester composites are 29.37, 36.59 and 38.85 kJ/m² for 15, 20 and 25% fiber content respectively. The IS increases with the increase of fiber content up to 25% by weight. The reason is that the PALF can increase the amount of energy required for pulling it out. Toughness is the major factor controlling the IS. Generally, the toughness of fiber reinforced polymer composites is dependent on the fiber, the polymer matrix and the interfacial bond strength [31].

4. Conclusion

The investigation of PALF twill fabric (1×1 twill weave) reinforced polyester resin matrix biocomposites lead to the following conclusions:

Successful fabrication of woven PALF fabric (1×1 twill weave) reinforced polyester composites with different fiber weight% is possible by simple hand lay-up technique. The mechanical properties of the composites such as tensile strength, bending strength and impact strength are also greatly influenced by the PALF weight content (%). It is revealed that at 25% fiber content the composites demonstrated improved mechanical properties.

5. References

[1] H. Ku, H. Wang, N. Pattarachaiyakoop, and M. Trada, "A Review on the Tensile Properties of Natural Fiber Reinforced Polymer Composites", *Composites: Part B*, Vol. 42, pp. 856–873, 2011. Doi:10.1016/j.compositesb.2011.01.010

[2] F.P.L. Mantia, and M. Morreale, "Green Composites: A Brief Review", *Composites Part A: Applied Science and Manufacturing*, Vol. 42, No. 6, pp. 579-588, 2011. Doi: https://doi.org/10.1016/j.compositesa.2011.01.017

[3] S.C. Das, and M.E.H. Nizam, "Applications of Fiber Reinforced Polymer Composites (FRP) in Civil Engineering", *International Journal of Advanced Structures and Geotechnical Engineering*, Vol. 03, No. 03, pp. 299-309, 2014.

[4] M.E.H. Nizam, and S.C. Das, "Geo Textile - A Tremendous Invention of Geo Technical Engineering", *International Journal of Advanced Structures and Geotechnical Engineering*, Vol. 03, No. 03, pp. 221-227, 2014.

[5] M.J. John, and S. Thomas, "Biofibres and biocomposites", *Carbohydrate Polymers*, Vol. 71, No. 3, pp. 343-364, 2008. Doi: https://doi.org/10.1016/j.carbpol.2007.05.040

[6] S.C. Das, D. Paul, M.M. Fahad, T. Islam, and M.E.H. Nizam, "Geotextiles – A Potential Technical Textile Product", *Journal of Scientific and Engineering Research*, Vol. 4, Issue. 10, pp. 337-350, 2017.

[7] M.S. Sreekala, M.G. Kumaran, and S. Thomas, *Composite Part A*, Vol. 33, pp. 763, 2002.

[8] A.K. Mohanty, M. Misra, and L.T. Drzal, "Natural Fibers, Biopolymers, and Biocomposites". *Boca Raton, FL: Taylor & Francis*, 2005.

[9] L.U. Devi, S.S. Bhagawan, and S. Thomas, "Mechanical Properties of Pineapple Leaf Fiber-Reinforced Polyester Composites," *J. Appl. Polym. Sci.*, Vol. 64, No. 9, pp. 1739–1748, 1997.

[10] N. Kengkhetkit, and T. Amornsakchai, "Utilisation of Pineapple Leaf Waste for Plastic Reinforcement: 1. A Novel Extraction Method for Short Pineapple Leaf Fiber," *Ind. Crops Prod.*, Vol. 40, pp. 55–61, 2012.

[11] P.S. Mukherjee, and K.G. Satyanarayana, "Structure and Properties of Some Vegetable Fibres: Part 2 Pineapple Fibre (Anannus Comosus)," *J. Mater. Sci.*, Vol. 21, No. 1, pp. 51–56, 1986.

[12] S.C. Das, M.T. Islam, M.A. Khan, M.A.A. Mamun, B.K. Mittro, J. Saha, and D. Paul, "Fabrication and Mechanical Characterization of PALF Plain Fabric Reinforced Polyester Biocomposites", *Proc. of the International Conference on Computer, Communication, Chemical, Materials and Electronic Engineering IC^{4}ME^2-2017*, Rajshahi, Bangladesh, Paper ID: 76, pp. 55, 2017.

[13] S. Kaewpiron, and C. Worrarat, "Preparation and Properties of Pineapple Leaf Fiber Reinforced Poly (Lactic Acid) Green Composites", *Fibers and Polymers*, Vol. 15, No. 7, pp. 1469-1477, 2014. Doi: 10.1007/s12221-014-1469-0.

[14] W. Smitthipong, R. Tantatherdtam, and R. Chollakup, "Effect of Pineapple Leaf Fiber-Reinforced Thermoplastic Starch/Poly(Lactic Acid) Green Composite: Mechanical, Viscosity, and Water Resistance Properties", *Journal of Thermoplastic Composite Materials*, Vol. 28, No. 5, pp. 717–729, 2015. Doi: 10.1177/0892705713489701

[15] M. Kottaisamy, T. Sornakumar, S.V.N. Rich, and K.P. Raja, "Development of Pineapple Leaf Fiber Reinforced Plastic Composites", *International Journal on Applications in Mechanical and Production Engineering*, Vol. 1, Issue 7, 2015, pp. 5-7, 2015.

[16] S.K. Chattopadhyay, R.K. Khandal, R. Uppaluri, and A.K. Ghoshal, "Influence of Varying Fiber Lengths on Mechanical, Thermal, and Morphological Properties of MA-*g*-PP Compatibilized and Chemically Modified Short Pineapple Leaf Fiber Reinforced Polypropylene Composites," *Journal of Applied Polymer Science*, Vol. 113, No. 6, pp. 3750–3756, 2009.

[17] R. Chollakup, R. Tantatherdtam, S. Ujjin, and K. Sriroth, "Pineapple Leaf Fiber Reinforced Thermoplastic Composites: Effects of Fiber Length and Fiber Content on their Characteristics", *Journal of Applied Polymer Science*, Vol. 119, pp. 1952–1960, 2011. Doi: 10.1002/app.32910

[18] N. Kengkhetkit, and T. Amornsakchai, "Utilisation of Pineapple Leaf Waste for Plastic Reinforcement: A Novel Extraction Method for Short Pineapple Leaf Fiber," *Ind. Crops Prod.*, Vol. 40, pp. 55–61, 2012.

[19] R. Chollakup, R. Tantatherdtam, S. Ujjin, and K. Sriroth, "Pineapple Leaf Fiber Reinforced Thermoplastic Composites: Effects of Fiber Length and Fiber Content on their Characteristics," *J. Appl. Polym. Sci.*, Vol. 119, No. 4, pp. 1952–1960, 2011.

[20] A. Danladi, J. Shu'aib, "Fabrication and Properties of Pineapple Fibre/High Density Polyethylene Composites", *American Journal of Materials Science*, Vol. 4, No. 3, pp. 139-143, 2014. Doi: 10.5923/j.materials.20140403.04

[21] R.M.N. Arib, S.M. Sapuan, M.M.H.M. Ahmad, M.T. Paridah, and H.M.D.K. Zaman, "Mechanical Properties of Pineapple Leaf Fibre Reinforced Polypropylene Composites," *Mater. Des.*, Vol. 27, No. 5, pp. 391–396, 2006.

[22] J. George, S.S. Bhagawan, and S. Thomas, "Improved Interactions in Chemically Modified Pineapple Leaf Fiber Reinforced Polyethylene Composites", *Composite Interfaces*, Vol. 5, No.3, pp. 201-223, 1997. Doi: 10.1163/156855498X00153

[23] S.C. Das, D. Paul, M.A.B. Siddiquee, J.M.M. Islam, and M.A. Khan, "Experimental Investigation and Analysis of Mechanical Behavior of Jute Fabric Reinforced Polyester Composites", *Proc. International Conference on Mechanical, Industrial and Energy Engineering 2016*, 26-27 December, 2016, Khulna, Bangladesh, Paper ID: ICMIEE-PI-160167.

[24] S.C. Das, D. Paul, M.A.B. Siddiquee, J. Saha, M.A. Khan, and J.M.M. Islam, "Study on the Mechanical Properties of Non-Woven Glass Fiber Reinforced Polyester Composites", *Proc. of the International Conference on Computer, Communication, Chemical, Materials and Electronic Engineering IC^{4}ME^2-2017, 26-27 January, 2017, Rajshahi, Bangladesh*, Paper ID: 75.

[25] S.C. Das, D. Paul, J.M.M. Islam, and M.A. Khan, "Effect of Gamma Radiation on the Mechanical Properties of PET Felt Reinforced Polyester Composites", *Proc. of the International Conference on Mechanical, Industrial & Energy Engineering 2016, 26-27 December, 2016, Khulna, Bangladesh*, Paper ID: ICMIEE-PI-160337.

[26] J. Saha, S.C. Das, M. Rahman, M.A.B. Siddiquee, and M.A. Khan, "Influence of Polyester Resin Treatment on Jute Fabrics for Geotextile Applications", *Journal of Textile Science and Technology*, Vol. 2, pp. 67-80, 2016. Doi: https://doi.org/10.4236/jtst.2016.24009

[27] M.T. Islam, S.C. Das, J. Saha, D. Paul, M.T. Islam, M. Rahman, and M.A. Khan, "Effect of Coconut Shell Powder as Filler on the Mechanical Properties of Coir-Polyester Composites", *Chemicals and Materials Engineering*, Vol. 5, Issue 4, pp. 75-82, 2017. Doi: 10.13189/cme.2017.050401

[28] M. Rokbi, H. Osmani, A. Imad, and N. Benseddiq, 2011, "Effect of Chemical Treatment on Flexure Properties of Natural Fiber-Reinforced Polyester Composite", *Procedia Engineering*, Vol. 10, pp. 2092-2097. Doi: https://doi.org/10.1016/j.proeng.2011.04.346

[29] A.V.R. Prasad, and K.M. Rao, "Mechanical Properties of Natural Fibre Reinforced Polyester Composites: Jowar, Sisal and Bamboo", *Materials & Design*, Vo. 32, No. (8-9), pp. 4658-4663, 2011. Doi: https://doi.org/10.1016/j.matdes.2011.03.015

[30] T.T.L. Doan, H. Brodowsky, and E. Mader, "Jute Fiber/Polypropylene Composites II. Thermal, Hydrothermal & Dynamic Mechanical Behavior," *Composites Science & Technology*, Vol. 67, No. 13, pp. 2707-2714, 2007.

[31] S.H. Masud, T.D. Lawrence, M. Manjusri, "A study on biocomposites from recycled newspaper fiber and poly(lactic acid)", J. Ind. Eng. Chem. Res., Vol. 44, pp. 5593-5601, 2005.