International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Research Paper
Available online at: www.jrrset.com
UGC Approved Journal No: 45483
Received on: 19.01.2018 Published on: 29.01.2018 Pages : 43-53

ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
Volume 6, Issue 1
January 2018.
JIR IF : 2.54
DIIF IF : 1.46
SJIF IF : 1.329

MECHANICAL CHARACTERIZATION AND WATER ABSORPTION BEHAVIOUR OF WOVEN BANANA AND GLASS FIBER REINFORCED POLYESTER COMPOSITES

Dipu Raj[1],Rakesh Raj[2], Joobith Banarji[3]
[1,2,3] Assistant Professor, Department of Mechanical Engineering
Vellappally Natesan college of Engineering, India

Abstract

Use of eco-friendly composites gain attraction due to its light weight and moderate strength in the recent years. Woven fabrics are attractive as reinforcement since they provide excellent integrity and conformability for advanced structural composite applications. The major driving force for the increased use of woven fabrics, compared to their non-woven counterparts is reduced manufacturing costs and increased resistance to impact damage. In this work, woven banana and glass fibre (WRM) fabrics are arranged in different stacking sequences to prepare different composite laminates. Woven banana fibre reinforced with glass fibre is expected to have high impact strength, flexural strength and tensile strength compared to laminate (non-woven) composites. Composites of different fibre weight fractions, layering patterns and weaving architecture will be tested for flexural strength, tensile strength and impact strength. The inter-laminar shear strength and water absorption behaviour of the fabricated composites are also focused. Proven to be of appreciable impact strength, this fibre could be used in crumble zone of passenger cars, shield of helmets, sports knee pads, elbow pads, acoustic shield, etc. Different types of hybrid laminates will be fabricated by hand lay-up and compression moulding method by using woven banana and glass fibres as reinforcing material with Isophthalic polyester resin. Scanning electron microscope (SEM) analysis is carried out to evaluate fiber matrix interfaces and analyze the structure of the fractured surfaces.

Keywords: fibers, Woven Banana fibers, Woven Hybrid Composites, Mechanical Testing, ILSS, SEM

1. Introduction

Composites are materials consisting of two or more chemically distinct constituents, on a macro-scale, having a distinct interface separating them. The natural fibers are renewable, bio-degradable, possess a good calorific value, exhibit excellent mechanical properties and can be incinerated for energy recovery have low density and are inexpensive. This good environmental friendly feature makes the materials very popular in engineering markets such as the automotive and construction industry. The incorporation of natural fibers with glass fiber improves the tensile and flexural strength and these composites can be used for medium load applications. At present the banana fiber is a waste product of banana cultivation, therefore without any additional cost these fibers can be obtained for industrial purposes. Now a days conventional material for the medium load applications are replaced by the natural fibre composite materials.

Optimum weight percentage of the fiber content in the composite also determines its mechanical properties and flexural properties are found to be increased linearly with fiber content up to 50 wt. %

[1]. The banana fibers which are alkali treated with 2% NaOH possess better mechanical properties [2] and studies exposed that treatment with 10% NaOH gives better thermo physical properties. With the combination of banana and sisal fiber, fiber length and weight percentage are the major factors in deciding the mechanical properties and in banana and sisal fiber with 50:50 weight percentage showed maximum tensile strength along with 40% weight fraction of total fiber content [3].

The use of banana fiber as reinforcing agent in cement and polymer based composites were reviewed from the point of view of status, physical, and mechanical properties and different surface treatments of banana fiber based composites. Due to low density, high tensile strength and low elongation at break of banana fibers, composites based on these fibers have very good potential use in the various sectors like construction, automotive, machinery, etc.[15]. The polymer banana reinforced natural composites is one of the best natural composites among the various combination. It can be used for manufacturing of automotive seat shells compared with the other natural fiber combinations [16].

The fracture toughness and Viscoelastic properties of banana/sisal fiber hybrid polymer composites were carried out with reference to the effect of fiber loading, frequency and temperature. The fracture toughness and energy release rate are found higher at 30 wt. % of hybrid composite. Results show that fracture toughness and strain energy release rate of Banana/Sisal sample are 4.39 $MPam^{1/2}$ and 6.17 kJ/m^2 respectively. This is due to the strong adhesion between fiber and matrix at 30 wt. percentage fiber loading [17].

The woven fabric composite materials have better out-of-plane stiffness, strength and toughness properties than laminate composites [18]. The selection of weave design is important as it has a higher influence on the tensile and impact properties of the dry fabric and composites.

It is observed that the various layering pattern has significant effect on the tensile, flexural and impact properties of the composite. The woven jute fibers were hybridized with woven banana fiber, the effect of hybridization is lesser when compared with the effect of layering sequences [19]. The tensile strength on the pseudo-stem banana woven fabric reinforced epoxy composite is increased by 85% compared to virgin epoxy. The flexural and impact strength increased when banana woven fabric was used with epoxy material. The banana fiber composite shows a ductile appearance with minimum plastic deformation [20].

Glass fiber reinforced polymer composites can be changed with a hybrid combination of sisal–jute with glass ply [24]. The banana-glass fiber hybrid composites have high tensile strength than other composites and can withstand the tensile strength of 39.8MPa followed by the hemp-glass fiber reinforced composites which shows the value of 37.5MPa. It is noted that these banana-hemp-glass fibers reinforced hybrid epoxy composites can be used as alternate material for synthetic fiber reinforced composite materials [25]. Banana fiber reinforced glass composites having highest ultimate tensile strength, flexural strength and impact strength compared to other specimens [26]. 50% Banana fiber with 50% epoxy resin composite materials can able to withstand higher loads compared to other combinations. Effect of glass fiber hybridization on randomly oriented natural fibers can be easily studied. Stacking sequence of banana and sisal fibers improves the strength and fiexural properties [27].

2. Experimental

2.1 Materials

2.1.1 Woven Banana fiber

The banana fibers are extracted from the pseudo stem of the banana plant. These are growing up to 5–10 feet. The length of the stalk depends on the height of the plant and its width is about 3–5 cm with a thickness of 1–2 cm. The fibers are located at the outer sheath of the stalk. The qualified stalk of the plant is cut to a length of 100 cm and its outer sheath is then removed. Then these sections are crushed between two roller drums with scraping blades at its circumference to remove the pulpy material between these fibers. The process of stripping the fibers from the stalk is known as tuxies. Finally the fibers are completely cleaned in water to remove the waste materials and then it is dried in sunshine for a few days to remove the moisture content.

2.1.2 Glass fiber

The fabricated laminates were made with woven roving (WRM) glass fiber mat as one of the reinforcement in the polyester matrix. These coarse cloths are used mainly in hand lay-up process.

The resin used in the study is commercially available and being used for a wide range of applications due to their ability to adhere to a wide variety of fillers and to form a densely cross-linked molecular structure on curing, which provides better stiffness, strength, dimensional stability and resistant to chemicals. The advantage of using polyester resin is that, there will not be any volatile by-products during curing and it gives 95% solid content on curing.

2.2 Making of Composites

For the preparation of composite laminates for this work, we using hand lay-up process followed by application of pressure using compression moulding. Hand lay-up is the simplest and low cost manufacturing method suitable for academic purposes. Initially the banana fibers are dried under the hot sun to remove the moisture content for more than 24 hours. In order to orientate the fiber in the composite material, the dried banana fibers are to be woven properly. The woven fiber mats of constant thickness were prepared from banana fibers of suitable length. Three different laminates were prepared with stacking sequences B/B/B (Laminate 1), G/B/B/G (Laminate 2) and G/B/G/B/G (Laminate 3). The weighted quantity of woven banana/ glass fiber mat and the polyester were taken, to fabricate the composites. The weight percentage of woven banana and glass fibres are shown in Table 1.

Table 1

Weight fractions of banana and glass fiber

Laminates	Banana Fiber (wt. %) Woven)	Glass Fiber (wt. %) WRM)
Laminate 1 **B/B/B**	44	0
Laminate 2 **G/B/B/G**	18	18
Laminate 3 **G/B/G/B/G**	24	36

A small amount of curing agent (hardener) was added to the polyester resin mixture and stirred for making woven banana and glass fiber reinforced composite panels of 270 × 200 × t mm size by hand lay-up and compression moulding process. The mixing ratio of polyester to hardener was 10:1 by weight. The hand lay-up process needs to be completed within the gel time of the polyester which is around 35 minutes. After the hand lay-up and compression moulding process, the laminates with different stacking sequences were allowed to dry at room temperature for 24 hours. The dried laminates are then cut up with different thickness as per ASTM standards for mechanical testing. Hand lay-up process and different stacking sequences of composites are shown in fig.1.

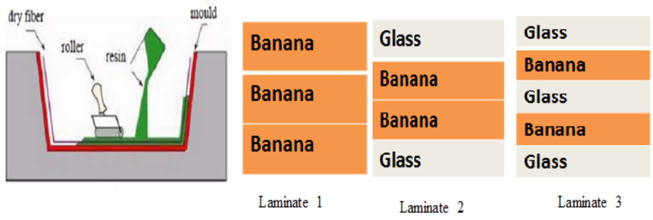

Fig.1 Hand Lay-up Process and Different Laminates

3. Mechanical Testing

3.1 Tensile Test

The tensile strength of the laminate was obtained according to the ASTM standard, ASTM: D3039. The tensile test was done on KALPAK UTM (Model no. KIC-2-1000-C with a maximum load capacity of 100 kN). The samples were tested at a loading rate of 2 mm/min. The tensile stress-strain curve is shown in Fig.2

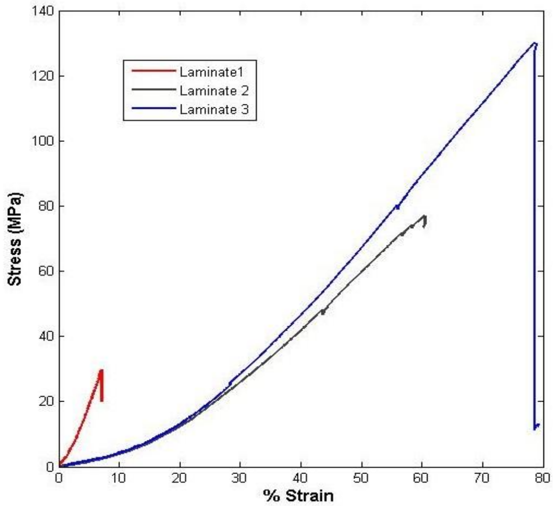

Fig.2 Tensile Test Results

By increasing the number of layers of banana fiber tensile strength of the composite is found to be increasing drastically due to better fiber matrix adhesion. Tensile strength and tensile modulus of different laminates are shown in table 2.

Table 2

Tensile Properties of Woven Banana and Glass Fibre Composites

Laminate	Tensile Strength (MPa)	Tensile Modulus (GPa)
Laminate 1	32	1.25
Laminate 2	78.5	5.80
Laminate 3	129	5.07

Results shows that the tensile strength of the woven banana composite (laminate 1) is 32 MPa. For Laminate 2, the strength is found to be increased to 78.5 MPa.

For laminate 3, strength increased by 80%, when compared to laminate 2. For laminate 3, produces an ultimate tensile strength of 129 MPa.

3.2 Flexural Test

The flexural test was performed on the KALPAK UTM (Model no. KIC-2-1000-C with a capacity of 10 kN). Dimensions of the specimen were made according to the ASTM standard ASTM: D790. The specimens were placed between two supports and the load is applied at the centre (three point bending test). The load was applied at a rate of 2 mm/min till the specimen fractures and breaks. The maximum load at failure was used to calculate the flexural stress.

Fig.2 shows the variation of flexural properties of various laminates tested. Laminate 3 exhibits higher flexural strength and modulus of 148 MPa and 12.02 GPa respectively. This shows that addition of glass fiber as the surface layer increases the strength and stiffness of banana fiber composite.

Figure 3 shows that the laminate 2 exhibit higher flexural strength and modulus than laminate 1.

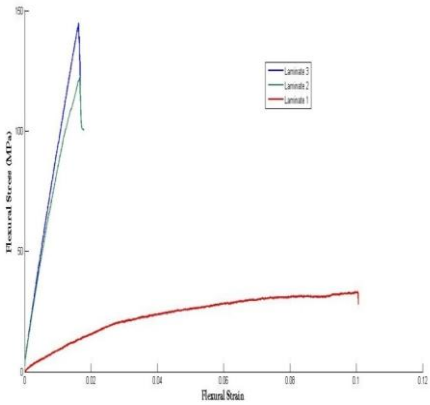

Fig.3 Flexural Test Results

When the numbers of layers are increased, delamination between the layers becomes the important mechanism of failure. The flexural modulus value for laminate 2 is 5.77 GPa and for laminates 3 is 12.02 GPa. Woven architecture has comparatively lesser influence on the flexural properties of the composite because of the presence of point loading and bending mode of failure of the composite. Flexural strength and flexural modulus of different laminates are shown in table 3.

Table 3

Flexural Properties of Woven Banana and Glass Fibre Composites

Laminate	Flexural Strength (Mpa)	Flexural Modulus (GPa)
Laminate 1	36	1.02
Laminate 2	119	5.77
Laminate 3	148	12.02

3.3 Impact Test

The impact strength of the laminates was tested by using Izod impact test rig. The standard dimension for the test is made according to the ASTM standard ASTM D 256. During the experiment, the specimen is placed in the testing machine and releasing the pendulum until it breaks. Using this test, the energy needed to break the material can be measured and it helps to measure the toughness of the material and the yield strength.

Impact strength of various laminates are shown in table 4.

Table 4

Impact Strength of Woven Banana and Glass Fibre Composites

Laminate	Impact Strength (J)
Laminate 1	6
Laminate 2	13.1
Laminate 3	15.2

The impact strength of composites can be increased with increase in the fiber weight fraction. The maximum value of impact strength 15.2 J is obtained for laminate 3.

By increasing the number of layers of woven banana mat in between the glass fiber skin layers, the strength can be increased to its maximum values. As the number of layers of fibers increases as in laminate 3, impact strength improved by 15% compared to laminate 2.

3.4 Interlaminar shear strength (ILSS) – Short Beam Test

The test is conducted to determine the bond strength between the layers of composites. Three point bending test with a low ratio of width to span (1:3) is used for ILSS test.

The interlaminar shear strength is obtained by using the expression,

$$F_{sbs} = 0.75 \frac{p}{bh} \quad \text{(MPa)}$$

Where, p = maximum load obtained during the test (N)
b = width of the composite (mm)
h = thickness of the composite (mm)

The interlaminar shear strength (ILSS) was determined according to the ASTM standard ASTM D 2344-06. The three point bending test was carried out on a KALPAK UTM (Model no. KIC-2-1000-C with a capacity of 10 kN) with a constant cross head speed of 2 mm/min. Fig.4 shows the plot of interlaminar shear strength for different laminates.

Interlaminar shear strength of various laminates are shown in table 5.

Table 5

ILSS of Woven Banana and Glass Fiber Composites

Laminate	ILSS (MPa)
Laminate 1	29.52
Laminate 2	33.68
Laminate 3	46.26

Experimental results shows that the interlaminar shear strength for laminate 1 is 29.52 MPa, which is higher than those of glass fiber reinforced composites with interlaminar shear strength of 25 MPa. For laminate 3 gives higher strength of 46.26 MPa compared to laminate 2 and laminate 1. The short beam shear strength of the hybrid composites was even higher than glass fiber reinforced composites due to the excellent hybrid performance of the hybrid interface.

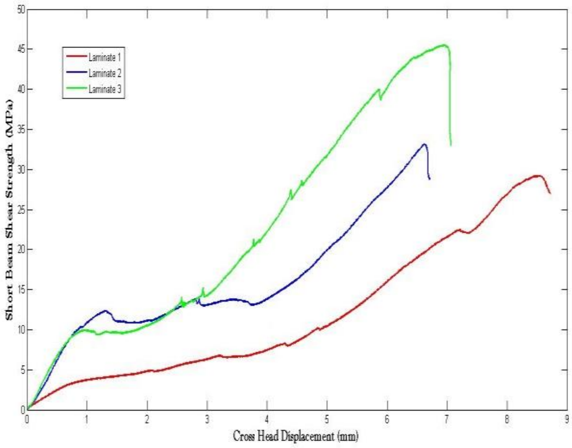

Fig.4 Interlaminar Shear Strength Results

3.5 Water Absorption Behaviour

Water absorption test carried out in accordance with the ASTM standard ASTM D570 procedure to predict the percentage of moisture absorption of the hybrid composites. For this test, specimens were immersed in water at room temperature for 24 hours. The samples were taken out randomly and weighed immediately, after moping out the water from the surface of the sample and using an accurate four-digit balance to find out the content of moisture absorbed. All the samples were dried until constant weight of the composite is reached before immersing in the water.

The percentage of water absorption is given by:

% of absorption = $(m_2 – m_1)/m_1$

Where, m_1 = mass of dry sample (gm)
m_2 = mass of wet sample (gm)

Water absorption behaviour of various laminates are shown in table 6.

Table 6
Water absorption behavior of various banana fiber samples

	n$_1$ (Mass of ry sample in m)	h$_2$ (Mass of vet sample n gm)	ercentage f water bsorption
Laminate 1 **B/B/B**	15	16	6.67
Laminate 2 **G/B/B/G**	11	13	18.18
Laminate 3 **G/B/G/B/G**	14	15	6.67

Experimental results show that the water absorption for laminate 2 (18.18%) were higher compared to laminate 1 and laminate 3.

4. Analysis Of Tested Specimen

4.1 Using Scanning Electronic Microscope (SEM)

Interfacial properties such as fiber–matrix interaction, fracture behavior and fiber pull-out of the composites after mechanical tests were studied using scanning electronic microscope (SEM). The fractured portions of the samples were cut and gold plated over the surface uniformly for final examination. The accelerating voltage used in this SEM analysis work is 15 kV.

4.2 Results of Scanning Electron Microscopy (SEM)

Figres–5 to 7 shows the micrograph of fractured specimen of tensile, impact and flexural test of banana fiber reinforced polyester composite (Laminate 1). The SEM micrograph of the sample subjected to tensile loading is shown in Fig.5. The reinforcement of the banana fibers and fiber fracture due to tensile loading are clearly shown in the micrograph. From the SEM micrograph obtained during tensile test, it can be found that the banana fiber composite (Laminate 1) exhibits a ductile appearance with minimum plastic deformation.

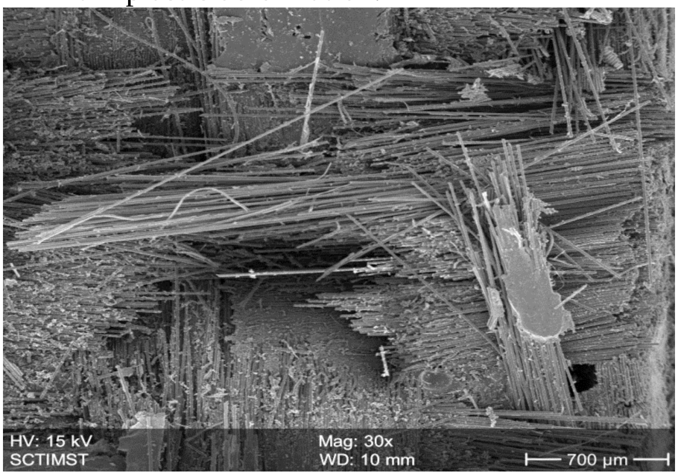

Fig.5 SEM analysis micrograph of banana fiber reinforced polyester composite subjected to tensile loading

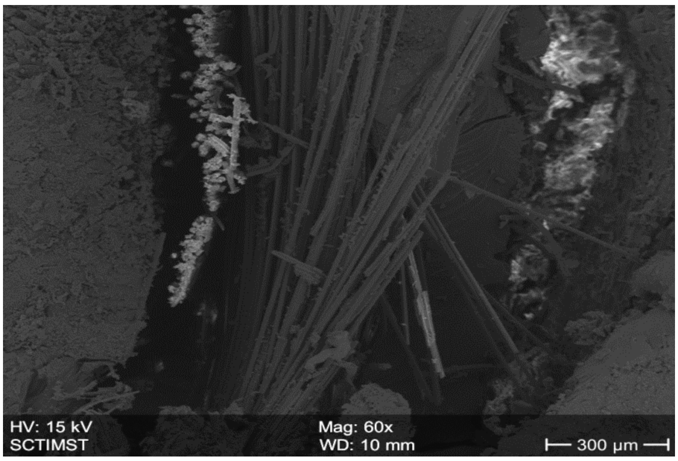

Fig.6 SEM analysis micrograph of banana fiber reinforced polyester composite subjected to impact loading

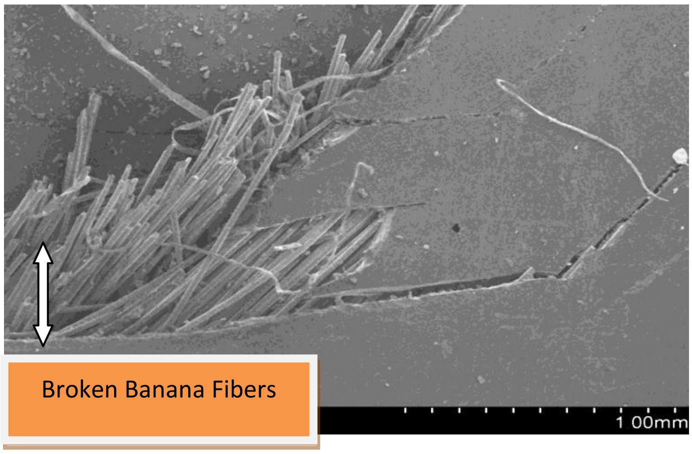

Fig.7 SEM analysis micrograph of banana fiber reinforced polyester composite subjected to flexural loading

The SEM micrograph of the banana fiber reinforced polyester composite subjected to impact loading is shown in Fig.5. The SEM image of the banana fiber reinforced polyester composite subjected to flexural loading is given in Fig.6. The figure shows that the broken banana fibers due to the application of flexural load are acting to the perpendicular direction of the banana fiber reinforcement.

6. Conclusion

The present investigation deals about the mechanical and water absorption property was studied for banana fiber and glass fiber reinforced polyester composites. Conclusions from this study are as follows:

- The banana hybrid combination with three layers of glass fiber (laminate 3) holds maximum tensile strength of 129MPa.
- The banana hybrid combination with three layers of glass fiber (laminate 3) holds maximum flexural strength of 148MPa.
- The banana hybrid combination with three layers of glass fiber (laminate 3) holds maximum impact strength of 15.2J.
- From various literature surveys it is found that for different types of composite materials, banana fiber composite possess lowest percentage of water absorption.
- From fracture studies, it has been noted that the number of voids present on the broken part of the composite material are less which shows the presence of fiber–polymer matrix interaction with the composite material.
- The banana fiber composite exhibits a ductile appearance with minimum plastic deformation.
- From the SEM analysis, the nature of fiber fracture due to mechanical loading, crack formation in the matrix layer and the matrix failure are clearly observed.

References

1. J. Girones, J.P. Lopez, F. Vilaseca, J.R. Bayer, P.J. Herrera-Franco, P. Mutje.Biocomposites from Musa textilis and polypropylene: evaluation of flexural properties and impactstrength.CompositeScience & Technology, 71 (2011), pp. 122–128

2. N. Venkateshwaran, A. Elayaperumal, D. Arunsundaranayagam. Fiber surface treatment and its effect on mechanical and visco-elastic behavior of banana/epoxycomposite. Mater Des, 47 (2013), pp. 151–159
3. N. Venkateshwaran, A. Elayaperumal, G.K. Sathiya.Prediction of tensile properties of hybrid-natural fibercomposites. Composites Part B, 43 (2012), pp. 793–796
4. H. Ku, H. Wang, N. Pattarachaiyakoop, M. Trada.A review on the tensile properties of natural fiber reinforced polymer composites.Composites Part B, 42 (2011), pp. 856–873
5. A.V.R. Prasad, K.M. Rao.Mechanical properties of natural fibre reinforced polyester. Composites: Jowar, sisal and bambooMater Des, 32 (2011), pp. 4658–4663
6. A.V.R. Prasad, K.M. Rao, G. Nagasrinivasulu. Mechanical properties of banana empty fruit bunch fiberreinforced polyester. CompositesIndian J Fibre Text Res, 34 (2009), pp. 162–167
7. G. Cicala, G. Cristaldi, G. Recca, G. Ziegmann, A. El-Sabbagh, M. Dickert.Properties and performances of various hybrid glass/natural fibre composites for curved pipes.Mater Des, 30 (2009), pp. 2538–2542
8. K. Liu, H. Takagi, Z. Yang.Dependence of tensile properties of abaca fiber fragments and its unidirectional composites onthe fragment height in the fiber stem.Composites Part A, 45 (2013), pp. 14–22
9. A.K. Bledzki, A. Jaszkiewicz, D. Scherzer.Mechanical properties of PLA composites with man-made cellulose and abaca fibres.Composites Part A, 40 (2009), pp. 404–412
10. A.K. Bledzki, A.A. Mamun, A. Jaszkiewicz, K. Erdmann. Polypropylene composites with enzyme modified abaca fibre.Composite Science& Technology, 70 (2010), pp. 854–860
11. S. Sangthong, T. Pongprayoon, N. Yanumet.Mechanical property improvement of unsaturated polyester composite reinforced with admicellartreated sisal fibers.Composites Part A, 40 (2009), pp. 687–694
12. C.P.L. Chow, X.S. Xing, R.K.Y. Li.Moisture absorption studies of sisal fibre reinforced polypropylene composites.Composite Science & Technology, 67 (2007), pp. 306–313
13. M. Boopalan, M. Niranjanaa, M.J. Umapathy.Study on the mechanical properties and thermal properties of jute and banana fiber reinforced epoxy hybrid composites.Composites Part B, 51 (2013), pp. 54–57
14. G. Lebrun, A. Couture, L. Laperriere.Tensile and impregnation behavior of unidirectional hemp/paper/epoxy and flax/paper/epoxy composites. ComposStruct, 103 (2013), pp. 151–160
15. N.Venkateshwaran and A.Elayaperumal.Banana Fiber Reinforced PolymerComposites -A Review. Article In Journal of Reinforced Plastics and Composites August 2010
16. M.Sakthivel,S.Ramesh.Mechanical Properties of Natural Fibre (Banana, Coir, Sisal) Polymer Composites.Science ParkISSN: 2321 – 8045Vol-1, Issue-1, July 2013
17. Avinash Kumar, Manoj Kumar Gupta, R. K. Srivastava, Harinder Singh.Viscoelastic Properties and Fracture Toughness of Hybrid Polymer Composite Using Banana/Sisal Fibre.International Journal of Advance Research In Science And EngineeringIJARSE, Vol. No.3, Issue No.7, July2014
18. S.M. Sapuan, A. Leenie, M. Harimi, Y.K. Beng. Mechanical properties of woven banana fibrereinforced epoxy composites.Materials and Design 27 (2006) 689–693
19. N. Venkateshwaranand A. ElayaPerumal. Mechanical and Water Absorption Properties of Woven Jute/Banana Hybrid Composites.Fibers and Polymers 2012, Vol.13, No.7, 907-914
20. M. A. Maleque, F. Y. Belal.Mechanical Properties Study Of Pseudo-Stem Banana Fiber Reinforced Epoxy Composite.The Arabian Journal for Science and Engineering, Volume 32, Number 2B October 2007 PP: 359-364
21. Zulkifli, Rozli; Azhari, CheHusna; Ghazali. Interlaminar Fracture Toughness of Multi-Layer Woven Silk/Epoxy Composites Treated with Coupling Agent. European Journal of Scientific Research;Feb2009, Vol. 27 Issue 3, p454

22. R. Yahya, S.M. Sapuan, M. Jawid, Z. Leman, E.S. Zainudeen. Effect of layering sequence and chemical treatment on the mechanical properties of woven Kenaf-aramid laminated composites. Materials and Design 67 (2015) 173-179
23. Zulkifli, Rozli; Azhari, CheHusna; Ghazali. Interlaminar Fracture Toughness of Multi-Layer Woven Silk/Epoxy Composites Treated with Coupling Agent. European Journal of Scientific Research;Feb2009, Vol. 27 Issue 3, p454
24. M. Ramesh, K.Palanikumar, K. Hemachandra Reddy.Mechanical property evaluation of sisal–jute–glass fiber reinforcedpolyester composites.Composites: Part B 48 (2013) 1–9
25. R. Bhoopathi, M. Ramesh, C. Deepa.Fabrication and Property Evaluation of Banana-Hemp-Glass Fiber Reinforced Composites.Procedia Engineering 97 (2014) 2032 – 2041
26. V.S. Srinivasan, S. RajendraBoopathy, D. Sangeetha, B. Vijaya Ramnath. Evaluation of mechanical and thermal properties of banana–flax basednatural fibre composite. Materials and Design 60 (2014) 620–627
27. V.P. Arthanarieswaran, A. Kumaravel, M. Kathirselvam. Evaluation of mechanical properties of banana and sisal fiber reinforced epoxy composites: Influence of glass fiber hybridization. Materials and Design Volume 64, December 2014, Pages 194–202