Journal of Materials Science & Surface Engineering, 6(5): 867-871
ISSN (Online): 2348-8956; 10.jmsse/2348-8956/6-5.3

Theoretical Modelling and Experimental Investigation on Mechanical Properties of Natural Fiber Reinforced By Epoxy Resin Matrices

Husain Mehdi[1] · Arshad Mehmood[2]

[1]Department of Mechanical Engineering, Meerut Institute of Technology, Meerut, India.

[2]Department of Mechanical Engineering, University of Buraimi Oman.

ABSTRACT

The composite material has a very wide area of research and it is attracting the interest to researchers, engineers and scientists due to its superior mechanical and physical properties like light weight, low density, high specific strength, low cost, and better mechanical properties. It has found wide application in automobile, aerospace and sporting industries. This work focused on study the mechanical properties of natural composite using theoretical and experimental verification. The theoretical models used are series and parallel, Halpin-Tsai, Modified Halpin-Tsai and Hirsch model for evaluation of tensile strength and tensile modulus. Experimental characterization was carried out as per ASTM D638 type-I by universal testing machine. The theoretical value of tensile strength and tensile modulus were compared with experimental results. It was found that the increase in the fiber volume fraction, increase the tensile strength, the maximum tensile strength was found 44 MPa for jute composite at 40% fiber weight, whereas minimum tensile strength was found 16.25MPa in coir fiber at 10% fiber weight.

© 2019 JMSSE and Science IN. All rights reserved

ARTICLE HISTORY

Received 16-01-2019
Revised 12-03-2019
Accepted 15-03-2019
Published 22-03-2019

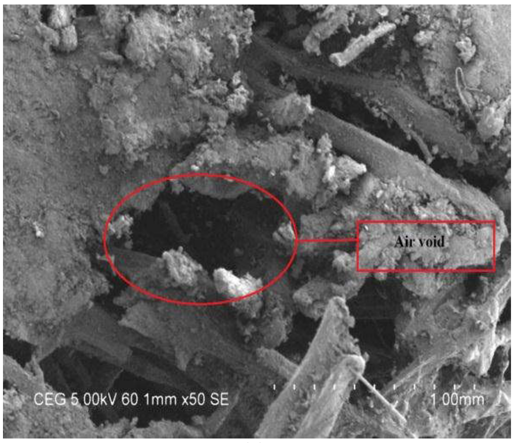
KEYWORDS

Tensile strength
Natural fiber
Epoxy resin
Hardener
Jute fiber
Coir fiber

Introduction

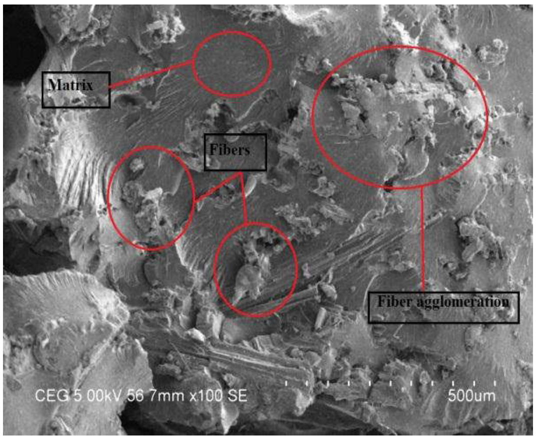
Most scientists and researchers have focused on the development of new fiber composite based on natural and synthetic fibers. In recent years, the mixed content of natural fibers has evolved because of growing concerns about global warming, environmental pollution and increased burden on fossil fuel reserves. There are some natural fibers whose strength is very good compared to existing synthetic fibers, which contributed to the development of this field. Natural fibers such as jute, pineapple, bamboo, coconut, etc., are discovered in low-load cases.

The replacement of steel with composite materials can be saved by 60-80% of component weight and 20-50% of aluminum alloy components [1]. Natural polymer-based packaging can also be used with natural fibers for an organic product. It does not cause an allergic sensation and burn the human skin. Organic compounds based on natural fibers attack attention because of their low cost, biodegradability, low density, high specific units, and recycling capacity [2-4]. Crushing of composite materials such as cracking matrix, breaking of fibers and delimitation. The fracture with fiber and flexible matrix plays an important role in laminated under tensile loads [5-8]. Mechanical properties of Jute reinforced polyester compound were assessed by a Jute composite and control of loading of different fibers. Overall 60% of fiber load showed higher tensile strength. The white jute polyester compounds exhibited the highest elastic strength, while the highest tensile strength was observed in the jute polyester compound [9]. Investigation of the mechanical properties of pine apple leaf fibers, fiberglass reinforced with mechanical fibers, has improved the effect of impact, flexible and tensile properties, so it shows a positive hybrid effect [10]. Typically composites contain a phase of fibers or particles that are harder and stronger than the continuous matrix phase and act as a major carrying load [15-12]. Flexural coefficient values from raw coconut fibers and jute fibers reinforce hybrid polypropylene compounds on different fiber loads, and the bending coefficient increases with fiber loading [13-17]. Composite materials reinforced by aluminum and synthetic fibers (Nylon and GFRP) [18-19] were examined from the analysis of computational modal analysis Mechanical properties of bleached composites showed better elasticity and impact strength, and high tensile strength was observed in controlled jute composites. The tensile strength and modulus of elasticity of 50% fiber loaded bleached jute epoxy composite is lesser than the corresponding of unbleached jute epoxy composite [20].



(a)

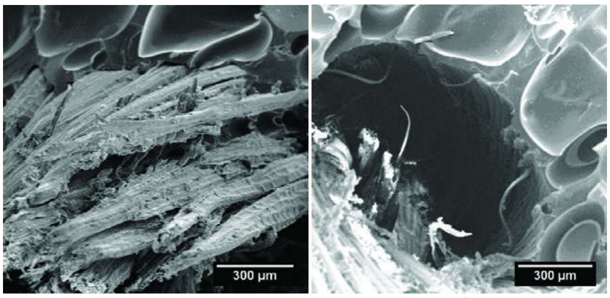
Corresponding Author: H Mehdi , Tel: +91 9259361558
Email: husainmehdi4u@gmail.com
© 2019 Science IN. All rights reserved
Contents lists available at http://www.jmsse.org/ & http://www.jmsse.in/



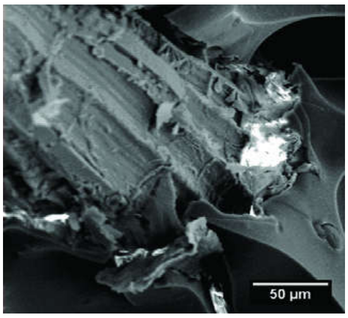
(b)

Figure 1: SEM images of Jute epoxy composite, (a) 500µm magnification, (b) 1 mm magnification [21]

The SEM images were taken for the samples to observe the microstructure. The images were taken for jute epoxy and jute polyester composites and the images were analyzed for better deduction of the reasons for failure and reduction in strength. The fiber distribution is clearly visible in the SEM images. 500 µm magnification fibers are clearly visible in which the fiber agglomeration and matrix without fiber is also visible clearly as shown in fig. 1(a). In fig. 1(b) the air gaps are clearly visible as indicated in the image. These air gaps reduce the strength of the composite. The fiber distribution and orientation are visible is in Fig.1 (a-b) [21].



(a) (b)



(c)

Figure 2: SEM images of fracture surface on the sisal (a) absence of matrix on the sisal fiber (100x), (b) void on resin (100x), (c) adhesion fiber matrix (500x) [22]

The tensile strength of sisal is 17 MPa and its elongation at maximum load and break are 8% and 11.3 % respectively. Sisal laminated presents elongation at break higher than 11% characteristics of ductile material. Tensile strength of sisal laminated shows an increase about 7 times with the addiction of humid sisal fibers when compared to polyurethane (PU) resin. Fig.2 shows the fracture surface to the PU/humid sisal laminated. In fig. 2(a-b), the presence of void in the resin that were formed during polymerization process is effective. Pull-out fibers of laminate is observed in the fig. 2(b). Regarding fiber surfaces, fig 2 (a) and (c), was not observed the presence of matrix adhered to the fibers, showing the low adhesion between fiber [22].

Experimental

Materials

In this work, mainly two natural fiber (coir and jute), epoxy resin and hardener were used as shown in fig.3. The fiber resin weight percentage was taken 20:80. The jute and coir fibers were chemically treated with NaOH solution. The coir fiber immersed in NaOH solution for 12 hours whereas jute fiber immersed for 24 hours and then taken out and dried in sunlight. The hardener used for epoxy resin LY 556 was HY951.

(a) (b)

Figure 3: (a) Jute fiber, (b) Epoxy resin LY556 and Hardener

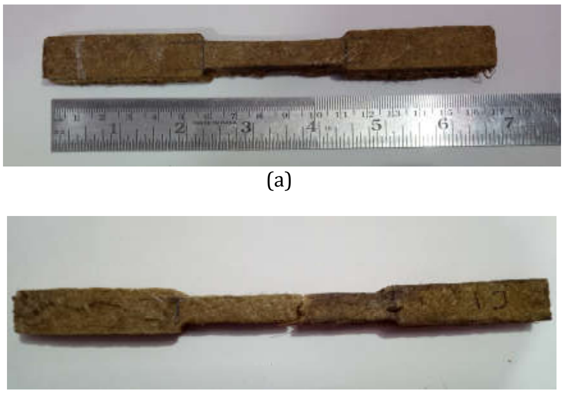
Experimental Analysis

The jute and coir fiber dried for 6 hours and were completely submerged in (epoxy resin + hardener), after that, the natural fiber were cured under pressure of about 40 kg/cm^2 at room temperature with the presence of 8 mm spacer to produce the composite on the same thickness for different contents as shown in fig. 4. The composite finally allowed cooling naturally to room temperature for 24 hours. The jute and coir mat composite were prepared with different fiber weight and the specimens of required dimension were cut and used for testing. The prepared composites were subjected to flexural and tensile strength. The specimen prepared for tensile test is according to ASTM D638 type-I standard as shown in fig. 5. The tensile test was performed using universal testing machine. All tests were performed at room temperature.

(a) (b)

Figure 4: (a) Mild Steel Mould, (b) Mould after filling fiber with epoxy

©2019 Science IN. All rights reserved


(a)

(b)

Figure 5: (a) Tensile test specimen, (b) Fractured Speceimen

Theoretical Modelling

Mechanical properties of fiber reinforced composites can be derived from experimentally and mathematical models. The advantage of a mathematical model is it reduces costly and time consuming analysis. A mathematical models may be used to find the best combination of constituent materials to satisfy material design considerations. The different theories are used to models the mechanical properties of fiber reinforced composites as

- Series and Parallel model
- Hirsch's model
- Halpin-Tsai equation
- Modified Halpin-Tsai equation
- Bowyer Bader's Model

Series and parallel model

According to these model tensile strength and tensile modulus were calculated by using equations as [23]

$$M_c = M_f V_f + M_m . V_m \quad (1)$$

$$T_c = T_f . V_f + T_m . V_m \quad (2)$$

Parallel Model

$$T_c = \frac{T_m T_f}{T_m V_f + T_f V_m} \quad (3)$$

$$M_c = \frac{M_m M_f}{M_m V_f + M_f V_m} \quad (4)$$

where, M_c, M_m and M_f are the tensile modulus of composite, matrix and fiber respectively. T_c, T_m and T_f are the tensile strength of the composite, matrix and fiber respectively. Assumption for parallel model, strain was uniform through lamina and for series model, stress was to be uniform in lamina.

Hirsch's model

It is combination of series and paralle model. Equation for calculation of tensile modulus and strength are as follow [24].

$$M_c = x\,(M_m V_m + M_f . V_f) + (1\text{-}x).\ \frac{M_m M_f}{M_m V_f + M_f V_m} \quad (5)$$

$$T_c = (T_m . V_m + T_f . V_f) + (1\text{-}x)\ \frac{T_m T_f}{T_m V_f + T_f V_m} \quad (6)$$

where, x is a parameter which determines the stress transfer between fiber and matrix.

Halpin – Tsai equation

Tensile strength and modulus of composite is given by equations [24]

$$M_c = M_m \left(\frac{1 + A_\eta V_f}{1 - \eta V_f}\right) \quad (7)$$

$$T_c = T_m \left(\frac{1 + A_\eta V_f}{1 - \eta V_f}\right) \quad (8)$$

$$\eta = \frac{(M_f/M_m) + 1}{(M_f/M_m) + A} \quad (9)$$

$$\eta = \frac{(T_f/T_m) + 1}{(T_f/T_m) + A}$$

where, η is relative module of fiber and matrix and A is the measure of fiber geometry, fiber distribution and fiber loading. The value of A is determined from the Einstein coefficient K [24].

Modified Halpin-Tsai equation

According to Modified Halpin-Tsai equation

$$M_c = M_m \left(\frac{1 + A_\eta V_f}{1 - \eta \psi V_f}\right) \quad (10)$$

$$T_c = T_m \left(\frac{1 + A_\eta V_f}{1 - \eta \psi V_f}\right) \quad (11)$$

where, ψ is depend on the particle packing fraction.

Bowyer Bader's Model

According to this model

$$M_c = M_f K_1 K_2 V_f + M_m . V_m \quad (12)$$

$$T_c = T_f . K_1 K_2 V_f + T_m . V_m \quad (13)$$

where, K_1, K_2 are the fiber orientation factor and fiber length factor respectively. All above models encoded in MATLAB for calculation of tensile strength of short coir fiber reinforcement with polypropylene matrix.

Results and Discussion

The jute and coir fiber reinforced by epoxy and hardener were subjected to mechanical characterization. Its mechanical properties are studied and compared with theoretical modelling. The result revealed that the jute epoxy exhibited better mechanical properties than the coir. The jute contains a fairly high proportion of stiff natural cellulose than the coir fiber. The mechanical properties of jute fibers tend to be controlled by the cellulose content and micro fibril angle based on the morphology and fiber composition. The processing time required jute-epoxy is comparatively lesser time than coir epoxy.

Tensile strength of composite material

When the volume fraction of the reinforcing fiber is lower than the critical quantity, the composite strength cannot be improved by addition of short fibers [25]. Such a drop in the tensile strength and modulus has been observed by

©2019 Science IN. All rights reserved

other researchers, where the tensile strength and modulus of banana fiber reinforced polyester composites ere decreased up to 10 wt% fiber weight content compared to those of neat resin. By increasing the fiber weight content to 22%, the tensile strength and young modulus were improved by 16% and 71% compared to those of the neat resin, respectively [26].

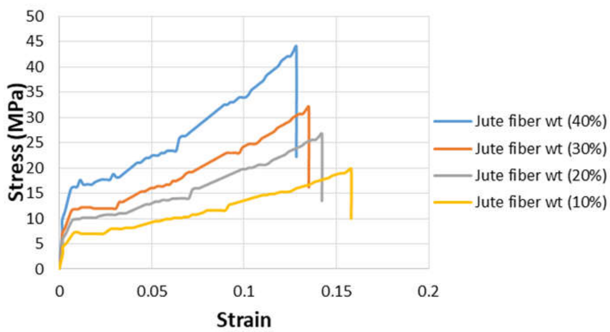


Figure 6: Stress-Strain diagram for jute fiber with different fiber weight

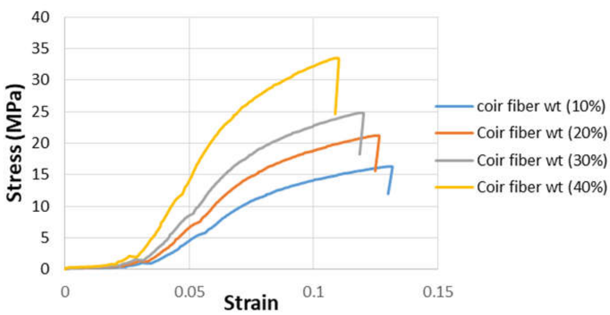
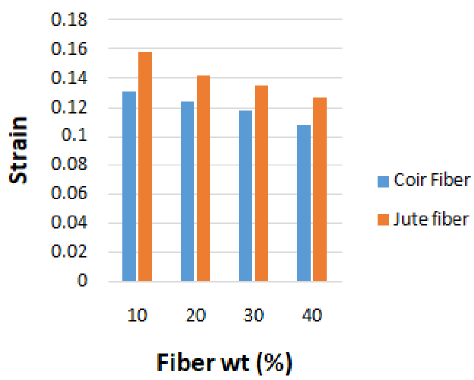
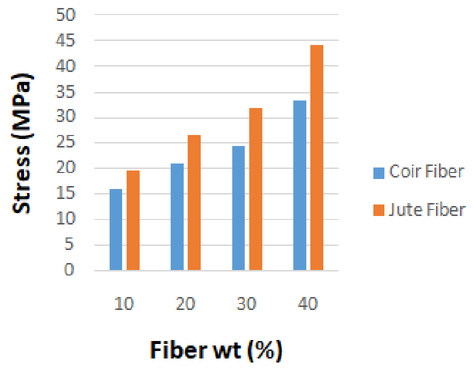


Figure 7: Stress-Strain diagram for Coir fiber with different fiber weight

Tensile test were determined according to ASTM D638 type-I standard. The measurements were done using a universal testing machine at room temperature. The stress-strain curves for both types of composite (jute and coir) for different weight contents as shown in fig. (6-7). It can observed that as the fiber weight content increase, the tensile strength of jute and coir composite increases. The effect of fiber weight content on the tensile strength of jute and coir composite as shown in fig. 8.



(a)



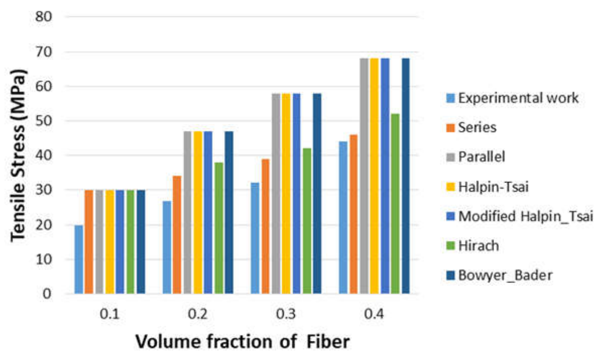
(b)

Figure 8: Comparison of jute and coir fiber, (a) Stress, (b) Strain

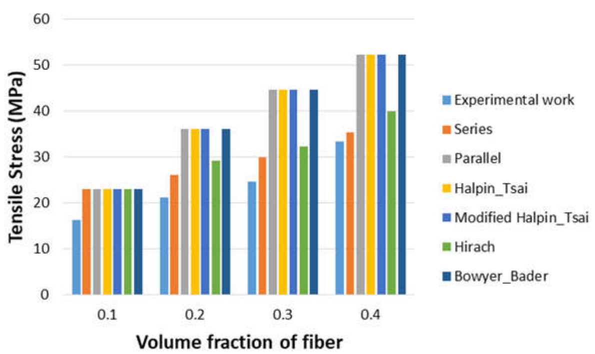
Validation with theoretical model

The bowyer and bader's model equations are function of fiber weight. The present work has been carried out by assuming volume fraction (10 to 40%) in calculation of tensile strength. It is observed that tensile strength increases with increase in fiber weight.

At low volume fraction of the fibers, the models show a good agreement. This may be due to uniform distribution of the fibers at applied load. It can also be seen that in all the cases the tensile strength increases regularly with increase in the volume fraction of fibers as shown in fig. 9.



(a)



(b)

Figure 9: Variation of theoretical tensile strength for different models, (a) Jute fiber, (b) Coir fiber

Conclusions

The present work shows that the jute fiber will become future alternative for the conventional material due o its enhanced mechanical properties and availability. The following important points have been carried out from the

©2019 Science IN. All rights reserved

above investigation. The maximum tensile strength of jute and coir composite was achieved at the 40 % fiber weight.
It was found that the increase in the fiber volume fraction, increase the tensile strength , the maximum tensile strength was found 44 MPa for jute composite at 40% fiber weight, whereas minimum tensile strength was found 16.25MPa in coir fiber at 10% fiber weight, Experimental investigation proved that the tensile strength increases with increase in volume fraction up to 40%.

References

1. Ajith Gopinath, Senthil Kumar. M, Elayaperumal A, Experimental Investigations on Mechanical Properties of Jute Fiber Reinforced Composites with Polyester and Epoxy Resin Matrices, Procedia Engineering, 2014, 97 , 2052-2063.
2. Yusriah, L., Sapuan, S. M., Zainudin, E. S., & Mariatti, M., Characterization of physical, mechanical, thermal and morphological properties of agro-waste betel nut (Areca catechu) husk fibre. Journal of Cleaner Production. 2014, 72, 174-180.
3. K.O. Reddy, C.U. Maheswari, M. Shukla, J.I. Song, A.V. Rajulu, Tensile and structural characterization of alkali treated Borassus fruit fine fibers. Composites Part B: Engineering. 2013, 44(1), 433-438.
4. M.H.P.S. Thakur Jawaid, H.A. Khalil, Cellulosic/synthetic fibre reinforced polymer hybrid composites: A review. Carbohydrate Polymers. 2011, 86(1), 1-18.
5. Mukul Kant Paliwal and Sachin Kumar Chaturvedi, An Experimental Investigation of TensileStrength of Glass Composite Materi als with Calcium Carbonate (CaCO3) Filler. Int. J. Emerg. trends in Eng. and Dev. 2012, 6 (2) , 303-309.
6. Cantwell WJ and Morton J. The impact resistance of composite materials - A review. Composites Part A 1991, 22, 347–362.
7. Richardson MOW and Wisheart MJ. Review of low-velocity impact properties of composite materials. Composites Part A 1996, 27, 1123– 1131.
8. Bibo GA and Hogg PJ. Review - The role of reinforcement architecture on impact damage mechanisms and post-impact compression b ehaviour. J. Mater. Sci. 1996, 31, 1115–1137.
9. Dash B N, Rana A K, Mishra H K, Nayak S K, Mishra S C and Tripathy S S. Novel low-cost jute-polyester composites. Part 1: Processing, m echanical properties and SEM analysis. Polym. Compos. 1999, 20 (1), 62–71.
10. Shah AN, Lakkad SC. Mechanical properties of jute reinforced plastics. Fiber Sci. Technol. 1981,15,41–46.
11. Antonio r. & Elizabeth p.sievert, “The story of Abaca”, Ateneo de Manila University Press,2009.
12. Jayabal, S., Natarajan, U. and Sathiyamurthy, S., Effect of Glass Hybridization and Stacking Sequence on Mechanical Behaviour of Interply Coir-Glass Hybrid Laminate. Bulletin of Materials Science, 2011, 34, 293-298.
13. Zamri, M.H., Akil, H.M., Bakar, A.A., Ishak, Z.A.M. and Cheng, L.W.. Effect of Water Absorption on Pultruded Jute/Glass Fiber-Reinforced Unsaturated Polyester Hybrid Composites. Journal of Composite Materials, 46, 51-61.
14. Onal, L. and Adanur, S., Effect of Stacking Sequence on the Mechanical Properties of Glass—Carbon Hybrid Composites before and after Impact. Journal of Industrial Textiles, 2012, 31, 255-271.
15. Gujjala, R., Ojha, S., Acharya, S.K. and Pal, S.K., Mechanical Properties of Woven Jute-Glass HybridReinforcedEpoxy Composite. Journal of Composite Materials, 2013, 47(1), 1-11.
16. Pujari, S., Ramakrishna, A. and Suresh Kumar, M., Comparison of Jute and Banana Fiber Composites: A Review. International Journal of Current Engineering and Technology, 2014, 2, 121-126.
17. Bledzki AK, Jaszkiewicz A, Scherzer D. Mechanical properties of PLA composites with man-made cellulose and abaca fibres. Compos Part A: Appl Sci Manuf, 2009,40(404),12.
18. Husain Mehdi Rajan Upadhyay, Rohan Mehra, Adit, Modal Analysis of Composite Beam Reinforced by Aluminium-Synthetic Fibers with and without Multiple Cracks Using ANSYS, International journal of Mechanical Engineering, 2014, 4 (2), 70-80.
19. Husain Mehdi, Anil Kumar, Arshad Mehmood, Manoj Saini, Experimental Analysis of Mechanical Properties of Composite Material Reinforced by Aluminium-Synthetic Fibers, International journal of Mechanical Engineering, 2014, 2 (2), 59-69.
20. Mishra, H.K., Dash, B.N., Tripathy, S.S., & Padhi, A Study on mechanical performance of jute –epoxy composites, Poly.-Plast.Technol. Eng., 2000, 39(1), 187–198.
21. Ajith Gopinath, Senthil Kumar, Elayaperumal A, Experimental Investigations on Mechanical Properties Of Jute Fiber Reinforced Composites with Polyester and Epoxy Resin Matrices, Procedia Engineering, 2014, 97, 2052-2063.
22. Andressa Cecília Milanese, Maria Odila Hilário Cioffi and Herman Jacobus Cornelis Voorwald, Mechanical behavior of natural fiber composites, Procedia Engineering, 2011, 10, 2022–2027.
23. Harjeet S Jaggi, yogesh kumar, Bhabani K. Satapathy, Analytical interpretatuon of structural and mechanical response of high dendity polyethylene/hydroxyapatite bio-composites, materials and design, 2012, 36, 757-766.
24. G.Kalaprasad, K Joseph, S. Thomson, Theoretical modelling of tensile properties of short sisal fiber reinforcement low dendity polyethylene composites, journal of materials science, 1997, 32, 4261-4267.
25. Y. Fu, B. Lauke, and Y. W. May, Science and Engineering of Short Fibre Reinforced Polymer Composites,CRCPressLLC, Washington, DC, USA, 2009.
26. L. A. Pothan, S. Thomas, and N. R. Neelakantan, “Short banana fiber reinforced polyester composites: mechanical, failure and aging characteristics,” Journal of Reinforced Plastics and Composites, 1997, 16(8), 744–765.

©2019 Science IN. All rights reserved