Mechanical Properties of Sisal/Coir Fiber Reinforced Hybrid Composites Fabricated by Cold Pressing Method

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Abstract: Bio-composites have less density and are environmental friendly materials that require less energy during production and subsequent machining. This paper reports the mechanical and water absorption properties of sodium hydroxide (NaOH) treated sisal and coir fiber reinforced epoxy resin thermo set hybrid composites. The hybrid composites were prepared by traditional cold pressing method at room temperature with applied pressure of 410.4 kg/cm2 for 3 hours pressurization time. The mechanical properties were characterized according to ASTM standards. Hybrid composites with 40wt% of sisal and coir fiber were found to possess higher tensile strength of 48.2MPa and flexural strength of 76.68 MPa among the fabricated hybrid composite specimens. Absorption of water increases with increasing fiber volume. The experimental result also show that the sisal and coir fibers are promising reinforcement for use in low cost bio-composites which have high strength to weight ratio.

Keywords: Cold pressing, Hybrid composite, Sodium hydroxide.

1. Introduction

The areas of application of polymer matrix composites (PMC's) have grown rapidly and have even found new markets. The use of cellulosic fiber materials as reinforcing fillers in polymer composite material products has increased by many folds in the last two decades. PMC materials can be fabricated either using of cellulosic or artificial fibers. Artificial fibers are petroleum or chemical based fibers. Artificial based composites are not able to decompose in environment but cellulosic fiber based composite easily decompose in soil after use. For the same reason, researchers are more attracted towards cellulosic fiber reinforced polymers. Cellulosic fibers exhibit superior mechanical properties such as flexibility, stiffness and modulus compared to synthetic (glass) fibers. The cellulosic fiber component may be coir, sisal, hemp, jute, wood, saw-dust, kenaf, pineapple leaf fiber, banana, abaca, bamboo, wheat straw or other fibrous materials. The advantages of cellulosic fibers include low cost, abundant availability, low density, low abrasive wear of processing machinery and healthier working condition (1). However, the adhesion between the cellulosic fibers and polymer matrices is generally insufficient (2). Using the cellulosic fibers reduces the weight by 10 %, lowers the energy needed for production by 80 % and 5 % reduction in cost of component compared to glass-reinforced composites (3). Cellulosic fiber reinforced composites are not exposed to strong mechanical impacts and non-structural components compare to synthetic fiber composites, which are widely used in high performance engineering applications such as in aerospace industry (4).

Comparatively other cellulosic fibers, sisal fiber possess high content of cellulosic and high tensile strength, (5), chopped, continuous and woven forms of sisal fiber reinforced composites are suitable application in polymer composites (6). Coir fiber is one of the major wastes found in the southern coastal regions of India. Sisal and coir fibers are hydrophilic in nature and large amount of hydroxyl groups will give hydrophilic properties. This property will lead to a very poor interfacial bonding between fiber and hydrophobic matrix and very poor moisture absorption resistance. To achieve good interfacial bonding and resistance of water absorption, fiber surface treatment must be carried out to obtain an enhanced interface between the hydrophilic fiber and hydrophobic polymer matrices. P. Noorunnisa Khanamet. et al. (4)studied the effect of different types of surface modification of sisal fibers on the tensile and flexural properties of sisal fiber reinforced composites. Cellulosic fiber surface treatments can significantly improve adhesion between fiber and matrix lead to ingress of matrix resin into the fibers (2). R. Iovino (7) investigated the aerobic bio-degradation of coir fiber reinforced in poly lactic acid (PLA). S. Harish et.al (8) compared the mechanical properties of coir/epoxy and glass/epoxy composites, results indicates that coir/epoxy composites can be used as a low load bearing thermoplastic composites. Coir/epoxy composite discloses more flexural strength than hemp/epoxy composite (9). Mechanical properties of composites are increased with increasing the incorporation of fibers to a certain limit and then decreased with further increase in fiber content (10). R. Narendaret.al (11) studied the mechanical properties, chemical resistance and flame resistance of coir fiber/nylon fabric reinforced epoxy resin hybrid composites, and suggested that hybrid composites can contribute to longer durability of the panels in moist conditions. N. Venkateshwaran et.al (12) found the mechanical and moisture absorption properties of sisal/banana fibers reinforced hybrid composites. The incorporation of sisal fiber with glass fiber reinforced polymer (GFRP) exhibited more tensile strength and less flexural strength than incorporation of jute fiber with GFRP composites (13). Girisha. C et.al (14) studied the mechanical properties of different wt. % of sisal/coir-epoxy hybrid composites after subjecting to water immersion tests. The literature survey indicates that the overall mechanical and water absorption properties of natural fiber reinforced hybrid composites are completely dependent on the amount and type of the fibers used. In this investigation, sisal and coir fiber were used as reinforcement and epoxy resin as the matrix to fabricate hybrid composites by cold pressing method. The tensile, flexural, and water absorption properties were investigated and reported.

2. Experimental Details

2.1 Materials used

Chopped sisal and coir fibers (harvested in 2014) were used as reinforcement materials. These fibers were procured from plants grown in Karnataka, India. Epoxy resin araldite (AW106) and corresponding hardener (HV 953) were used to fabricate hybrid bio-composite. This is a low temperature curing epoxy system. The matrix material was prepared with mixture of araldite epoxy and hardener in the ratio of 10:1.

2.2 Fiber surface treatment

In order to improve the adhesion between the fibers and matrix, fibers were subjected to surface treatments. Sodium hydroxide is the most commonly used chemical for cleaning/bleaching the surface of cellulosic fibers. Both sisal and coir fibers (chopped) were soaked in 10wt% NaOH solution for 10 hours. The treated fibers were washed in distilled water in order to neutralize excess of NaOH. Both treated sisal and coir fibers were dried in sun light for two days before using as reinforcement in the synthesis of composite.

2.3 Hybrid composite preparation

Simple compression molding technique was used to fabricate hybrid composite in cast iron mold at high pressure. Hydraulic pressing machine was used to fabricate the specimens. Both male and female dies were coated with a thin layer of poly vinyl alcohol (PVA) to ensure the superior surface finish of laminate. Epoxy resin and hardener were mixed in a bowl to prepare the matrix material. Sisal and coir fibers were mixed and added in to matrix. The amount of reinforcement was varied from 10% to 50% in steps of 10%. A well-mixed mixture of matrix and fibers was poured into the female die cavity. The male die was placed on the female die and pressurized to 410.4 kg/cm^{2}from hydraulic pressing machine for 3 hours. Steps involved in fabrication of hybrid composites by hydraulic pressing machine as shown in fig.1.

(a) Thin layer of PVA coated dies

(b) Mixture of matrix and reinforcement filled in die

(c) Die pressing by Hydraulic pressing machine

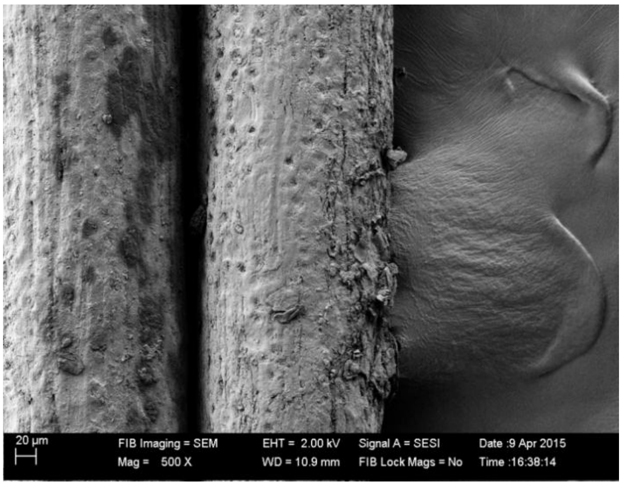
(d) Fabricated composite specimen

Fig.1 Various stages of composite fabrication using compression molding

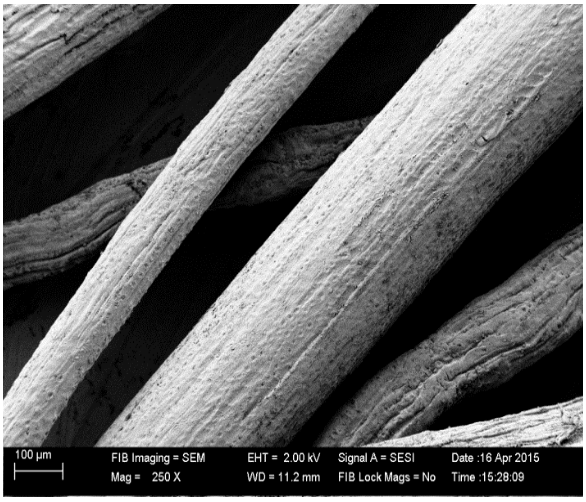
3. Results and Discussion

3.1. SEM images of untreated and treated fibers

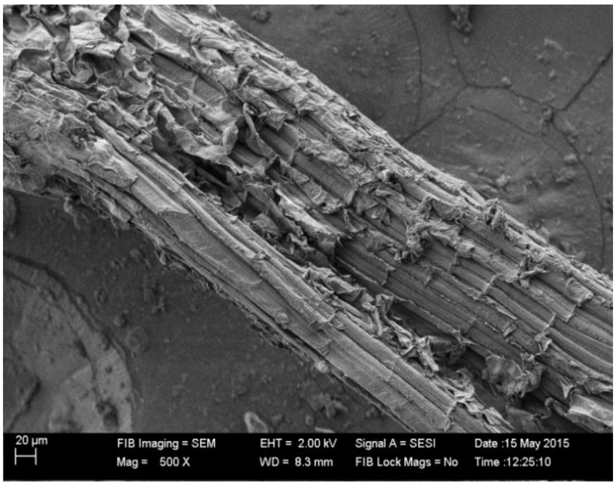
Fig. 2shows the appearance of without treated and alkali treated of coir fiber and sisal fiber. fiber. Initially fiber surface will usually be covered with a layer of substances, which may include pectin, lignin and other impurities. The fiber surface will not be smooth, but will have nodes and irregular stripes. After the sodium hydroxide treatment, most of the lignin, pectin and impurities are removed resulting in rougher surface and also small voids are produced on the fiber surface. These voids will increase the mechanical bonding between the matrix and fibers during composite fabrications.



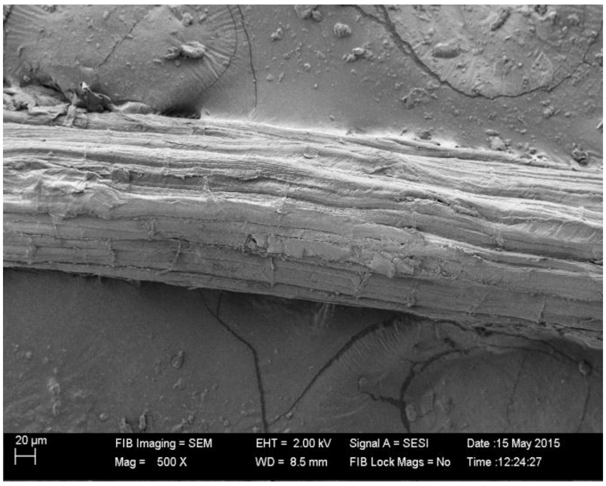
(a) Coir fiber before NaOH treatment



(b) Coir fiber after NaOH treatment



(c) Sisal fiber before NaOH treatment

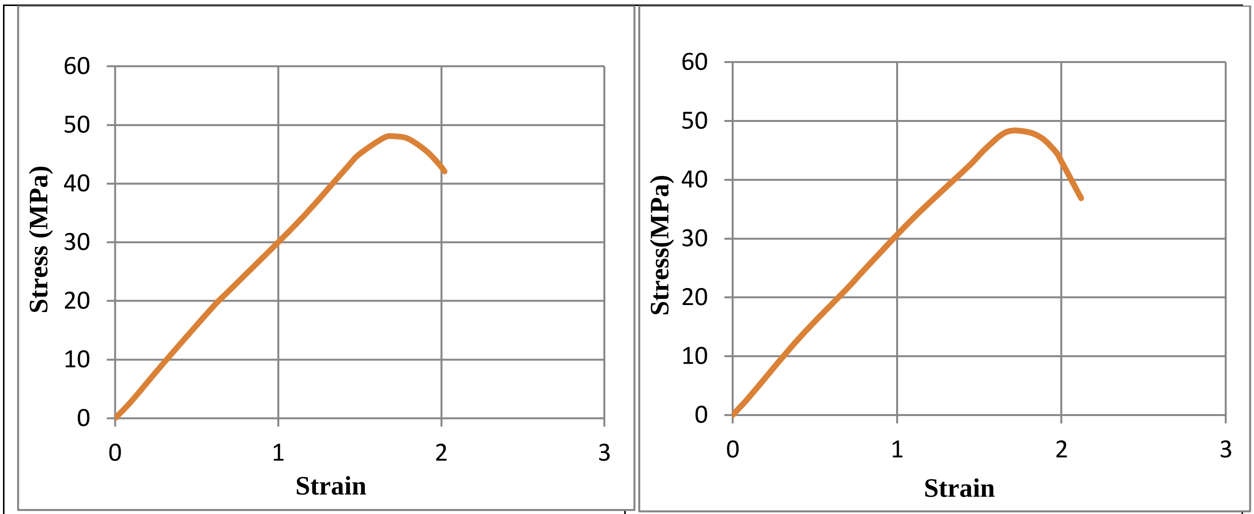


(d) Sisal fiber after NaOH treatment

Fig.2 Scanning Electron Micrograph images

3.2. Mechanical properties

Tensile and flexural tests were carried out according to ASTM D-3039 and ASTM 790-03 standards respectively. Four specimens were tested for each test and average value was considered for the analysis. Fig. 3 shows, the stress strain curves of 30wt% and 40wt% of sisal/coir fiber reinforced hybrid composite specimens. The tensile strength of sisal/coir fiber reinforced epoxy resin hybrid composites at different percentage of fiber loading is shown in fig 4.The tensile strength of hybrid composite increases with increasing fiber content up to 40wt % and then decreases with further addition of fibers. During tensile loading, partially separated micro-pores are created, which obstruct stress propagation between the sisal/coir fiber and epoxy resin matrix. As the fiber loading increases, the degree of obstruction increases, which in turn increases the stiffness. Without reinforcing epoxy resin based composite has a 24.78MPa tensile strength and 40wt% sisal/coir fiber reinforced hybrid composite discloses 48.2MPa tensile strength. A 40wt% sisal/coir fiber reinforced hybrid composite increases 48.58% tensile strength of hybrid composite.



(a) 30wt% sisal/coir fiber reinforced

(b) 40wt% sisal/coir fiber reinforced

Fig.3 Stress v/s strain curves of sisal/coir fiber reinforced hybrid composites.

The variation of the flexural strength for different weight percentage of sisal and coir fiber reinforced hybrid composites is shown in fig 5. The flexural strength increases with fiber loading up to 40 wt. %.Sisal and coir fiber are of higher modulus. Higher fiber concentration demands higher stress for the same deformation. Therefore, the incorporation of sisal and coir fibers into soft epoxy resin matrix resulted in an increase of the strength. Without reinforcing epoxy resin based composite has a 52.92MPa flexural strength and 40wt% sisal/coir fiber reinforced hybrid composite discloses 76.68MPa flexural strength. A 40wt% sisal/coir fiber reinforced hybrid composite increases 30.1% flexural strength of hybrid composite.

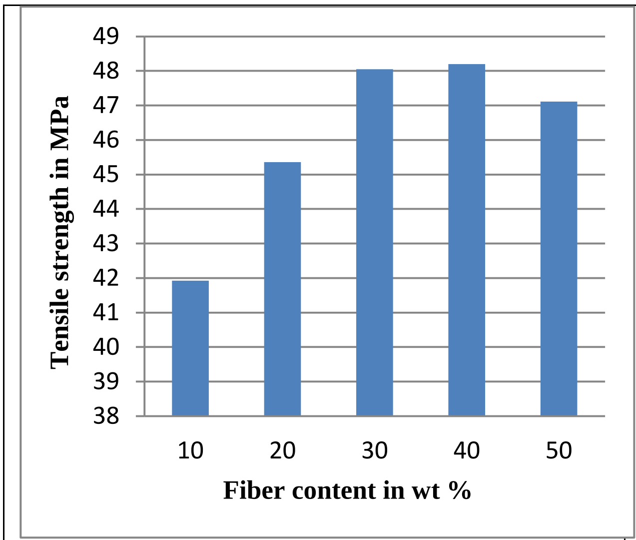


Fig.4 Tensile strength of hybrid composites

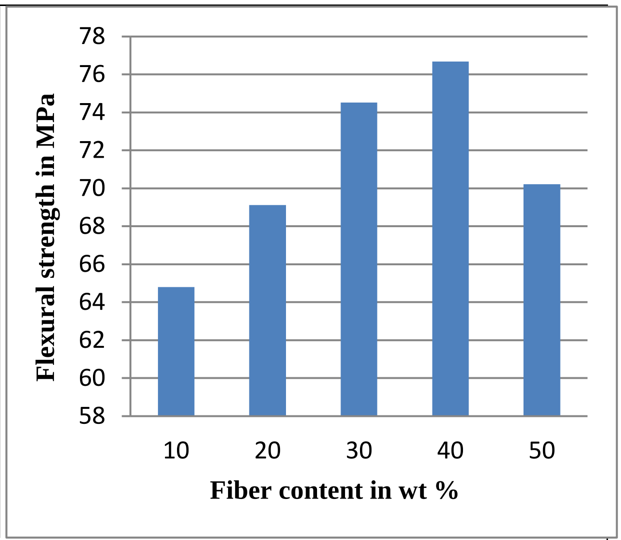


Fig.5 Flexural strength of hybrid composites

3.3. Water absorption of hybrid composites

Water absorption property of sisal/coir-epoxy resin hybrid composites was evaluated according to ISO 62:1999 standard procedure. Fabricated hybrid composite specimens were dried in oven at 50^0C and cooled to room temperature. After weighing the dried specimen to an accuracy of 0.1mg, they were immersed in distilled water in a plastic tub at room temperature. Once in 24 hours, the specimens were taken out from plastic tub, all the water from the surface was removed with clean cloth and the specimens were weighed. Same procedure was repeated for 28 days. The percentage of water absorption of sisal and coir fiber reinforced hybrid composites increases with increasing the fiber content.

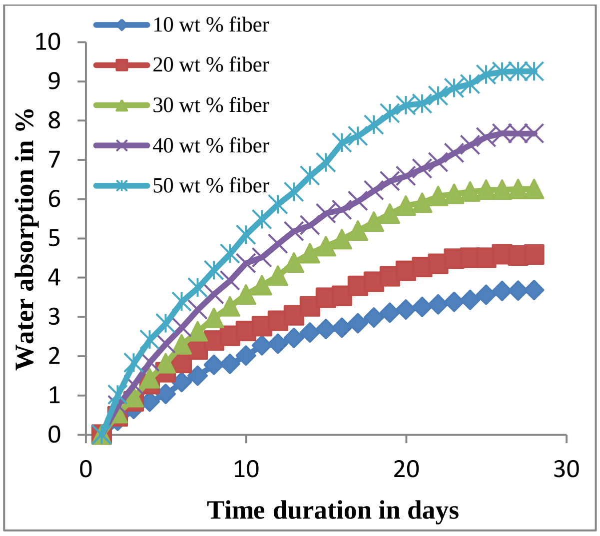


Fig.6 Wt.% of moisture absorption of different sisal/coir content of hybrid composites

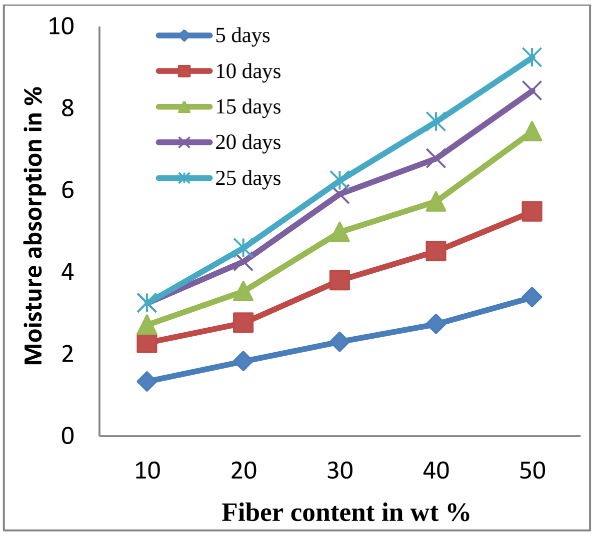


Fig.7 Variation in the amount of moisture absorption with increase in fiber content.

The percentage of water absorption was plotted against the time (days) as shown in Fig 6 which shows that the water absorption becomes stable after 25 days. Fig 7 shows the variation in the amount of moisture absorption with increase in fiber content. This shows that the moisture absorption increases with the increase in fiber content. The figure also shows that the moisture content increases with the increase in the soaking duration.

4. CONCLUSION

Experimental investigation of tensile, flexural and water absorption properties of different wt. % of sisal/coir fibers reinforced epoxy hybrid composites lead to the following conclusions.

1. Successful fabrication of cellulosic fibers reinforced hybrid composites can be achieved by traditional compression molding method.

2. 40wt% of sisal/coir fibers reinforced hybrid composite exhibits more tensile and flexural strength than other hybrid composites.

3. Water absorption (%) behavior reveals that the absorption of water content of hybrid composites increases with increase in the reinforcement of fiber content.

5. References

1. Alves C, Ferrao PMC, Silva AJ, Reis LG, Freitas M, Rodrigues LB, Alves DE. "*Ecodesign of automotive components making use of natural jute fiber composites*," J Cleaner Prod 2010:18; 313–327.
2. Min ZhiRong, Ming Qiu Zhang, Yuan Liu, Gui Cheng Yang, Han Min Zeng, "*The effect of fiber treatment on the mechanical properties of unidirectional sisal-reinforced epoxy composites*" Composites Science and Technology 61 (2001) 1437–1447.
3. Geethamma V G, Thomas Mathew K, Lakshminarayanan R, Sabu Thomas, "*Composite of short coir fibers and natural rubber: Effect of chemical modification, loading and orientation of fiber*," Polymer-6, 1998; 1483–90.
4. P. Noorunnisa Khanam, H. P. S. Abdul Khalil, G. Ramachandra Reddy, S. Venkata Naidu, "*Tensile, Flexural and Chemical Resistance Properties of Sisal Fibre Reinforced Polymer Composites*: Effect of Fibre Surface Treatment," J Polym Environ (2011) 19:115–119.
5. Mukherjee PS, Satyanarayana K G, "*Structure and properties of some vegetable fibers: Part I Sisal fiber*." J Mater Sci 1984; 19:3925–34.
6. Yang G C, "*Sisal fiber/resin composites*." MSc thesis, Zhongshan University, Materials Science Institute, 1996.
7. R. Iovino, R. Zullo, M.A. Rao, L. Cassar, L. Gianfreda, "*Biodegradation of poly(lactic acid)/starch/coir bio-composites under controlled composting conditions*", Polymer Degradation and Stability 93 (2008) 147-157.
8. S. Harish, D. Peter Michael, A. Bensely, D. Mohan Lal, A. Rajadurai, "*Mechanical property evaluation of natural fiber coir composite*", Materials Characterization 60 (2009) 44–49.
9. Akash, Venkatesh Gupta, K V SreenivasRao, Prasad C B, Prabilsonkhadka, "*Comparative Evaluation of Mechanical and Water Absorption Properties of Pure Epoxy Resin, Coir Fiber/Epoxy Resin and Hemp Fiber/Epoxy Resin Composite*" International Journal Of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.55 (2015)
10. Samia Sultana Mir, Nazia Nafsin, Mahbub Hasan, Najib Hasan, Azman Hassan, "*Improvement of physico-mechanical properties of coir-polypropylene bio-composites by fiber chemical treatment*" Materials and Design 52, (2013), 251–257.
11. R. Narendar, K. Priya Dasan, Muraleedharan Nair, "*Development of coir pith/nylon fabric/epoxy hybrid composites: Mechanical and ageing studies*", Materials and Design 54, (2014), 644–651.
12. N. Venkateshwaran, A. ElayaPerumal, A. Alavudeen, M. Thiruchitrambalam, "*Mechanical and water absorption behaviour of banana/sisal reinforced hybrid composites*," Materials and Design 32 (2011) 4017–4021.
13. M.Ramesh, K.Palanikumar, K.Hemachandra Reddy, "*Comparative Evaluation on Properties of Hybrid Glass Fiber- Sisal/Jute Reinforced Epoxy Composites*", Procedia Engineering 51 (2013) 745 – 750.
14. Girisha.C, Sanjeevamurthy, Gunti Rangasrinivas, Manu.Srinivas, "*Sisal/coconut coir Natural fibers – Epoxy Composites: Water absorption and Mechanical Properties*", International Journal of Engineering and Innovative Technology (IJEIT), Volume 2, Issue 3, 2012.