International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 05 | May 2020 www.irjet.net p-ISSN: 2395-0072

Mechanical Properties of Natural Fiber Reinforced Hybrid Polymer Composites: A Review

Mr. Berhanu Tolessa[1], Dr. Balkeshwar Singh[2]

[1]Research Scholar, Department of Manufacturing Engineering, Addis Ababa Science and Technology University, Addis Ababa, Ethiopia
[2]Professor, Mechanical Design & Manufacturing Engineering, Adama Science and Technology University, Adama, Ethiopia

---

Abstract - *Natural fibers have a great role in the industrial processes that reduce carbon emissions and recyclable materials that minimize waste. An extra degree of flexibility in fiber composites can be obtained by making what are called hybrid composites, wherein one uses more than one type of fiber. Cost-performance effectiveness can be increased by judiciously using different reinforcement types and selectively placing them to get the highest strength in highly stressed locations and directions. In hybrid composites, the cost can be minimized by reducing the carbon fiber content, while the performance is maximized by optimal placement and orientation of the fiber. Because of their characteristics, natural fibers have recently become attractive to researchers as an alternative method for fibers reinforced composites. This review paper summarized the applications and various properties of natural fibers such as hemp, jute, sisal kenaf and was utilized to substitute glass fiber.*

Key Words: natural, hybrid composite, mechanical properties, FRP composite.

1. INTRODUCTION

A composite material can be defined as a combination of two or more materials that results in better properties than those of the individual components used alone. In fiber-reinforced polymer (FRP) composite, reinforcement may either include natural fibers or synthetic fibers in the polymer matrix. Natural fibers gate attention over synthetic fibers to become the better replacement of synthetic fibers. The main advantages of composite materials are their high strength and stiffness, combined with low density, when compared with bulk materials, allowing for a weight reduction in the finished part. Nowadays natural fibers are a lot utilized in the place of synthetic fibers because of their environmental benefits such as biodegradability, high strength to weight ratio, good mechanical properties, low weight, and economic advantages. Natural fibers can be gained from plants such as banana, sisal, bamboo, kenaf, jute, bamboo and sugarcane [1]. Natural fibers now dominate the automotive, construction and sporting industries by its superior mechanical properties. Natural fibers economical less weight and environmentally superior alternatives to synthetic fibers. Despite these advantages, natural fibers have some limitations such as low impact strength and high moisture absorption properties. These problems can be reduced by combing different materials (hybridization) techniques. This can increase the mechanical properties of the materials. Many investigators have been converted on quite many types of natural fibers and their mechanical properties of composite materials [2]. The effects of chemical treatments on reinforcements and matrix modification of unidirectional (UD) sisal fibers mixed with epoxy and polyester matrix [3]. Outputs have indicated that the NaOH treatment improved slightly the fatigue resistance. They investigated the influence of reinforcement (jute, hemp, and flax, glass), stacking sequence and fiber content on the fatigue response of composite materials [4]. As a result, natural fiber composites are under intense investigation because of their potential as alternatives for synthetic fibers. The replacement of conventional materials and synthetic composites with natural fiber composites can thus become a reality, contributing to the creation of a sustainable economy. An ideal natural fiber composite is fully bio-degradable under controlled conditions and is composed only of short cycle renewable plants. On different research papers in fibers extraction and chemical treatments, fiber-matrix adhesion, or processing conditions, natural fiber composites are currently considered a viable replacement for glass composites in many applications in terms of both mechanical strength and a lower price. Actually, by treating the fibers with coupling agents, engineering the fiber length, and combining with the best possible matrix, very interesting characteristics are achievable. Compared with synthetic fibers, energy requirements for processing are much lower, and energy recovery is also possible [5]. Hybridization or a combination of natural fibers with glass fibers also constitutes a possible way in which the mechanical properties could be improved. The

natural fibers have low amounts of CO_2 emission and no abrasion during processing. Ramie textile applications have been replaced by synthetic fibers, mainly in clothes [6]. The recent relevant investigations about polymer hybrid composites, and a limited number of investigations related to hybridization of ramie with another natural or synthetic fiber. The scholars investigated polyester/hybrid ramie-cotton fabric composites, molded by compression [7]. In this present study, PPLSF/CF different length short fiber is reinforced polyester hybrid composite fabricated and determined the workable, flexural, impression and water immersion behavior of the fabricated composite. The best way in which the environment could be conserved is by using renewable and nontoxic natural materials, and all efforts should be undertaken them competitive.

2. LITERATURE REVIEW

Because of the worldwide availability of sisal and pineapple fibers, most researchers have to be to focus on these fibers. The large research efforts in fiber extraction and chemical treatments, fiber-matrix adhesion, or processing conditions, natural fiber composites are currently considered a viable replacement for glass composites in many applications in terms of both mechanical strength and a lower cost. Some researchers are taking alone fibers for research and some had taken a collection of these fibers with other synthetic and natural fibers for research work. Some scholars were prepared composite of pineapple fiber and PHBV resin of variety fiber weight ratio varies from 20% to 30% [8]. Sisal-glass fiber hybrid composites with the help of unsaturated polystyrene were prepared [9]. Composite materials are generally engineered materials made from two or more constituents with different physical or chemical properties, which the rest separate and distinct within the finished structure [10]. The composite should also have properties which better than the properties of the individual constituents that make up the composites [10, 11]. Generally, composite materials are classified and related to constituents as shown in figure 1.

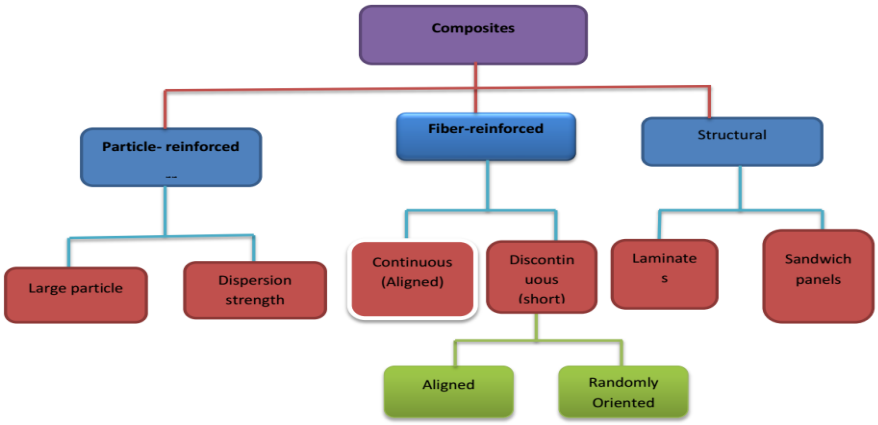

Fig.1. Composite Materials Classification [10, 11].

3. FIBER REINFORCED POLYMER COMPOSITE

Fiber composites may be classified according to the nature of the matrix and the fiber. FRP Composites comprise two main constitutes: the thermosetting resin matrix and the fiber reinforcement. The role of matrix resin is to keep the fibers in required place and orientation similarly common matrix materials include epoxy, phenolic, polyester, polyurethane, polyetheretherketone (PEEK), Vinyl ester, etc. The load exerted into the composites is disseminated into the fibers utilizing matrix. Because fibers are mostly brittle, the resin is the source of toughness for a composite [12]. Several factors are present for fiber to be utilized so extensively throughout the world as the fiber-reinforced in polymer composition can increase the mechanical properties including fracture toughness and tensile strength of the composition while contrasting the fiber and the polymer [13]. Fiber-reinforced polymer composites are as shown in Figure 2. So, we can see from the matrix point of view; total we can classify polymers into two groups, one is thermosets and thermoplastics. The matrix that we have is thermosets or thermoplastics and the reinforcement; that is a synthetic fiber and a natural fiber; from natural fiber mostly occurring are jute, banana, sisal, flax, helm fiber.

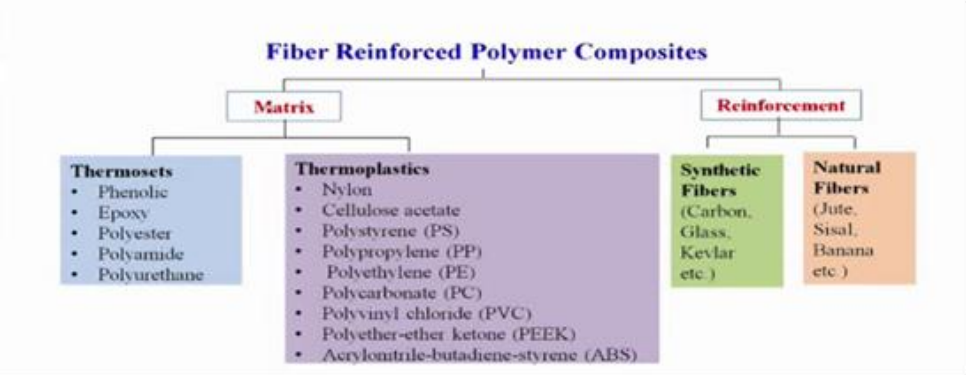

Fig.2. Fiber Reinforced Polymer Composites

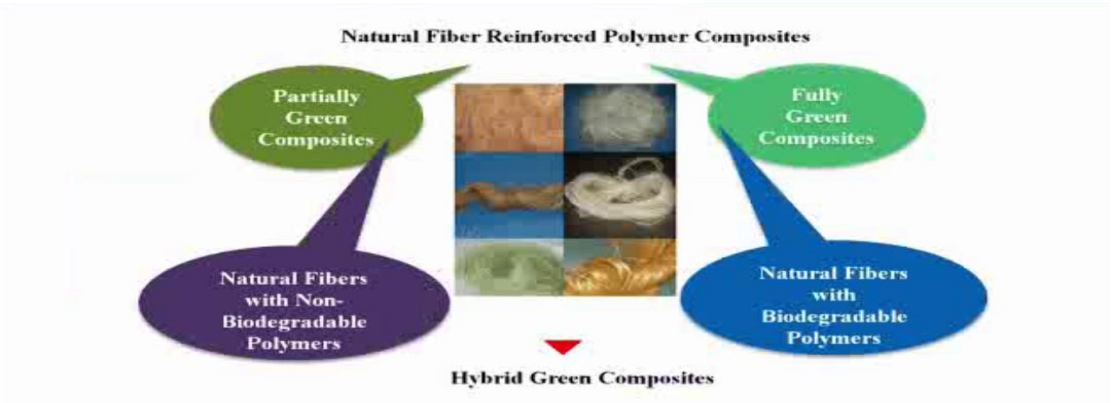

Fig.3. Natural Fiber Reinforced Polymer Composites.

Then again we can have natural reinforced polymer composites also in which the natural fibers are used as reinforcement which is shown in figure 3. So, natural fiber reinforced polymer composites; we have partially green composites; in partially green composites and have natural fibers with non-biodegradable polymers. The reinforcing agent that is the fibers are biodegradable or naturally occurring, but the polymer of the matrix is not biodegradable; it is a synthetic matrix. For fully green composites, natural fibers with biodegradable polymers. Hybrid fibers can use as reinforcement for reinforcing the polymer matrix. By using these can achieve the best properties as the reinforcing elements or reinforcing members in polymer-based composites. Sub classifications of fiber reinforced composite materials are shown in figure 4.

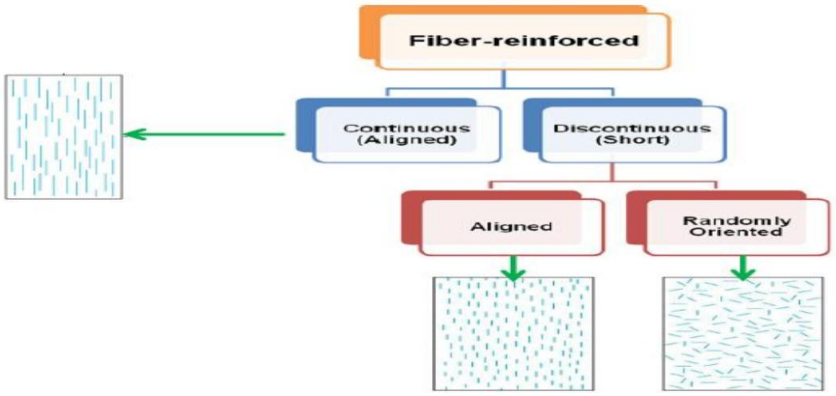

Fig.4. Fiber Reinforced Composite materials Sub classification

The concept of composites was not invented by human beings; it is found in nature. The mixing of fiber with other materials is to improve performance. For example, mixing husks in clay is an example of a particulate composite. A composite material is formed by reinforcing fibers in a matrix resin. The reinforcement can be fibers, particulates, or whiskers, and the matrix materials can be metals, plastics, or ceramics.

4. NATURAL FIBERS

Natural fibers are a major renewable resource material through the word specifically in the topics. Natural fibers can be considered as naturally occurring composites consisting mainly of cellulose fibrils embedded in a lignin matrix. Generally, there are two types of fibers are available i.e. natural fiber and synthetic or artificial fiber. Natural fiber is eco-friendly, is composed of vegetables, minerals, and animals where vegetables used for this purpose are: bamboo, hemp, sugarcane bagasse, flax, and banana while the animals' components include wool, skin, and hair. The minerals like ceramic and asbestos are needed for producing natural fiber [14]. The second form is synthetic fiber is produced by human beings it is a combination of glass fiber, carbon fiber, and aramid [15]. There is a large market and need for the fiber-reinforced polymeric composition specifically for the synthetic fiber as it is used in producing pipes, in tanks, sports' goods, and construction of bridges, boat hulls, automotive industry, and aircraft secondary structure while thermoset matrices and thermoplastic need natural fiber [16].

5. MECHANICAL PROPERTIES OF NATURAL FIBER COMPOSITES

Most of the investigations made on natural fiber composites pretended that their mechanical properties are strongly affected by various factors such as volume fraction of fibers, fiber ratio, fiber-matrix adhesion, fiber orientation, etc. Several studies have been made on different natural fibers like kenaf, hemp, flax, and jute to investigate the effect of these fibers on the mechanical properties of composite materials. The Mechanical Properties of jute fabric-reinforced polyester composites and found that they have better strength than those of wood-based composites. On bamboo and Bamboo Fiber Reinforced Composites- Bamboo is largely considered as one of the most vital non-timber forest resources because of the high socio-economic advantages of bamboo-based products. Natural fibers are lignocellulosic; they possess good acoustic insulation properties along with the novel thermal properties as compared to the other artificial or synthetic fibers. The mechanical properties of synthetic fibers are better as compared to natural fibers, but that can be further increased by various surface treatments of fibers as alkali treatment silane treatment, etc. Natural fibers are possessing high specific modulus, high specific strength, low densities, etc. are the reasons, of high need in the industries for the change of the composites. Because of these reasons, the natural fibers are largely utilized for various applications in green composites [17].

6. INFLUENCE OF FILLER ON MECHANICAL PROPERTIES

The physical and mechanical properties of Al_2O_3 filled jute reinforced epoxy composites are investigated [18]. They experimented to sort out the effect of filler on properties of composites. For example jute and Al_2O_3 taken as reinforcement and epoxy as a matrix, they observed that hardness, strength, flexural and tensile modulus increased with an increase in the fiber and filler materials. The mechanical properties of woven banana fiber, kenaf fiber, and banana/kenaf hybrid fiber composites investigated in this work. The mechanical properties of sisal, jute, and glass fiber reinforced polyester composites investigated [19]. [20] Studied the mechanical properties of composites of chemically treated fibers from the husk of areca nut and fibers from the fruit of tamarind. They observed that treated fibers indicated well outputs when compared to untreated fibers. They also noticed that the strength of hybrid composites increases with an increase in the volume fraction of fiber in the hybrid composites. From the investigation, it was found that all the hybrid natural fiber composites indicate ultimate mechanical properties for 40%-50% of the fibers reinforcements. [18, 20] on literature add filler materials the result concluded that physical and mechanical behaviors of composites can be modified by adding a filler phase to the matrix body during the composite preparation. The incorporation of filler in the composite is to improve mechanical and tribological properties which is shown in figure 5.

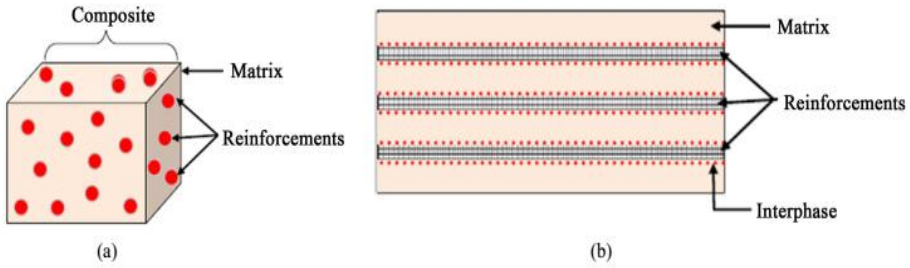

Fig.5. (a) Explains the composition of laminate which includes a resin as a matrix and fiber as reinforcement and (b) indicate interphase of matrix and reinforcement.

7. EFFECT OF PROCESS PARAMETERS ON MECHANICAL CHARACTERISTICS

Under the effects of parameters on Mechanical Characteristics, scholars investigate the effect of weight percentage of jute fiber reinforced in polypropylene-based composites and found out that mechanical properties increased as jute weight percentage increased up to 40% [21]. [22] Concluded that the mechanical properties of composites such as tensile strength and compressive strength of natural fiber composite were reported and compared with the data for glass/epoxy composites. [23] Studied the mechanical properties of jute/glass reinforced polyester with water absorption conditions. [24] Reviewed the mechanical properties of jute/glass-reinforced epoxy hybrid laminate with varying hybrid sequences and pure glass jute and epoxy composite and they were compared by using had layup technique and laminates were prepared with a total of four piles by varying the direction of glass and jute. It is found out that hybrids have well properties than pure jute and epoxy alone but less than pure glass. The different types of fiber orientation used for the laminate manufacturing is as shown in figure 6.

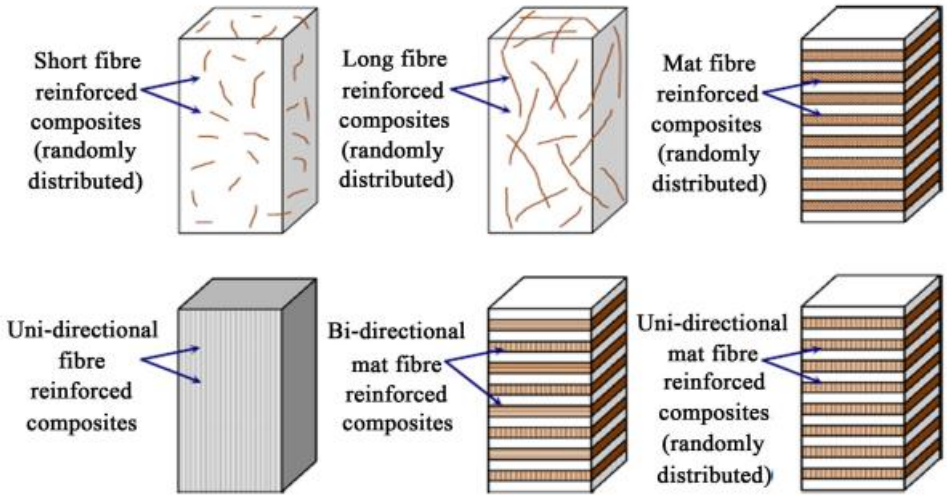

Fig.6. Different types of fiber orientation used for the laminate manufacturing.

[25] Examined the effects of many layers and fiber directions on the mechanical properties of the composites. The outcome shows that the mechanical properties of laminated have improved by adding the number of layers. The optimum properties were obtained in the case of a composite at 5 layers. The composite at 0-degree fibber direction and 0-degree cutting direction have high mechanical properties than the other cases. The fabrication of composites mainly influenced the properties of the composites. The mechanical properties such as tensile, flexural and impact strength can be modified by fabricating the composites using different mechanisms are as shown in table 1. Figure 7 indicates that varieties of natural fibers which are manufactured by plants.

Table 1. Properties of various natural fibers.

Fiber type	Density Kg/m3	Water absorption %	Modulus of elasticity E (Gpa)	Tensile strength (Mpa)
Sisal	800-700	56	15	286
Roselle	800-750	40-50	17	170-350
Banana	950-750	60	23	180-430
Date palm	463	60-65	70	125-200
Cocoanut	145-380	130-180	19-26	120-200
Reed	490	100	37	70-140

Fig.7. Varieties of natural fiber which are produced by plants.

8. CONCLUSIONS

The utilization of natural fiber as reinforcement in polymer composites was tested from the outlook of position and expectations of natural fibers, fabrication, and characterization of natural fiber, fiber surface refitting using various fillers and properties change in the natural fiber-based polymer composites. Comparing natural fibers with glass fiber reinforced composites found that natural fibers were greater in industrial applications. Moreover, because of the usage of natural fibers in various engineering utilization and construction industries, it provides a way for economic growth in rural areas. Natural fibers economical less weight and environmentally superior alternatives to synthetic fibers. Despite these advantages, natural fibers have some limitations such as low impact strength and high moisture absorption properties. Hybridization or a combination of natural fibers with glass fibers also constitutes a possible way in which the mechanical properties could be improved. The natural fibers have low amounts of CO_2 emission and no abrasion during processing. Composite materials are generally engineered materials made from two or more constituents with different physical or chemical properties, which the rest separate and distinct within the finished structure. FRP Composites comprise two main constitutes: the thermosetting resin matrix and the fiber reinforcement. The role of matrix resin is to keep the fibers in required place and orientation similarly common matrix materials include epoxy, phenolic, polyester, polyurethane, polyetheretherketone (PEEK), Vinyl ester, etc. Most of the investigations made on natural fiber composites pretended that their mechanical properties are strongly affected by various factors such as volume fraction of fibers, fiber ratio, fiber-matrix adhesion, fiber orientation, etc. Under the effects of parameters on Mechanical Characteristics, scholars investigate the effect of weight percentage of jute fiber reinforced in polypropylene-based composites and found out that mechanical properties increased as jute weight percentage increased up to 40%. The effects of several layers and fiber directions on the mechanical properties of the composites. The outcome shows that the mechanical properties of laminated have improved by adding the number of layers.

REFERENCES

[1] Samuel, O.D., Agbo, S., and Adekanye, T.A. (2012) Assessing Mechanical Properties of Natural Fibre Reinforced Composites for Engineering Applications. Journal of Minerals and Materials Characterization and Engineering, 11,780-784. http://dx.doi.org/10.4236/jmmce.2012.118066

[2] Satyanarayana KG, Sukumaran K, Mukherjee PS, Pavithran C, Pillai SGK (1990) J CemeConc Compos 12(2):136.

[3] Towo AN, Ansell MP. (2008) Fatigue evaluation and dynamic mechanical thermal analysis of sisal fiber-thermosetting resin composites, Journal of Composite Science and Technology. 2008; 68(9):25–32.

[4] Shah DU, Schubel PJ, Clifford MJ, Licence P. (2013)Fatigue life evaluation of aligned plant fiber composites through S–N curves and constant-life diagrams, Composite Science and Technology. 2013; 74:139-49.

[5] Kim, W., Argento, A., Lee, E., Flanigan, C., Houston, D., Harris, A., and Mielewski, D.F. 2011. High strain-rate behavior of natural fiber-reinforced polymer composites. Journal of Composite Materials 46:1056–1065.

[6] Margemi FM, Monteiro SN, Bravo Neto J, Rodriguez RJS, and Soares BG. (2010). The dynamic-mechanical behavior of epoxy matrix composites reinforced with ramie fibers. Revista Matéria. 15:164-171.

[7] Paiva Júnior CZ, De Carvalho LH, Fonseca VM, Monteiro SN, and D'Almeida JRM. (2004).Analysis of the tensile strength of polyester/hybrid ramie–cotton fabric composites. Polymer Testing. 23:131-135. http://dx.doi.org/10.1016/ S0142-9418(03)00071-0.

[8] N. Netrawali & S. Luo(1999), Interfacial & mechanical properties of environment friendly "green composite" made from pineapple fibers, Journal of material science.

[9] V. Naga Prasad et al. (2011), Compressive & impact properties of sisal/glass fiber reinforced hybrid composites, International Journal of Fiber and Textile Research.

[10] Autar K. Kaw (2006). "Mechanics of Composite Materials". Taylor & Francis Group.

[11] Daniel Gay, Suong V. Hoa and Stephen W. Tsai (2003). "Composite materials: Design and Applications". CRC Press LLC, Florida.

[12] Bhanawat & Patil: ' Textile fiber composite and their application' International Journal of Science Innovations and Discoveries, Volume 2, Issue 2, March-April 2012 pp50-61.

[13] Cheung, H-y, Ho, M-p, Lau, K-t, Cardona, F & Hui, D: 'Natural fibre-reinforced composites for bioengineering and environmental engineering applications', Composites Part B: Engineering, vol. 40, no. 7, pp. 655-63,2009.

[14] John, J, Gangadhar, SA & Shah, 'Flexural strength of heat-polymerized polymethyl methacrylate denture resin reinforced with glass, aramid, or nylon fibers', The Journal of prosthetic dentistry, vol. 86, no. 4, pp. 424-7,2001.

[15] Powell, PC, Engineering with fiber-polymer laminates, Springer, New York,1994.

[16] G. Yuvaraj B. Vijaya Ramnath, A. Abinash (2016). Investigation of Mechanical Behaviour of Sisal Epoxy Hybrid Composites, Vol 9(34), DOI: 10.17485/ijst/2016/v9i34/101004

[17] Thakur, V.K., Singha, A.S. and Thakur, M.K, 2011, "Green Composites from Natural Cellulosic Fibers, Germany: GmbH & Co. KG, 2011.

[18] Swain, P.T.R. and Biswas, S. (2014) Physical and Mechanical Behavior of Al2O3 Filled Jute Fiber Reinforced Epoxy Composites. International Journal of Current Engineering and Technology, 2, 67-71. http://dx.doi.org/10.14741/ijcet/spl.2.2014.13

[19] Alavudeen, A., Rajini, N., Karthikeyan, S., Thiruchitrambalam, M. and Venkateshwaren, N. (2015) Mechanical Properties of Banana/Kenaf Fiber-Reinforced Hybrid Polyester Composites: Effect of Woven Fabric and Random Orientation. Materials and Design, 66, 246-257. http://dx.doi.org/10.1016/j.matdes.2014.10.067

[20] Sanjeevamurthy, G.C., Rangasrinivas, G. and Manu, S. (2012) Mechanical Performance of Natural Fiber-Reinforced Epoxy-Hybrid Composites. International Journal of Engineering Research and Applications (IJERA), 2, 615-619.

[21] Berhanu, T., Kumar, P. and Singh, I. (2014) Mechanical Behaviour of Jute Fibre Reinforced Polypropylene Composites. 5th International & 26th All India Manufacturing Technology, Design and Research Conference (AIMTDR 2014), Guwahati, 12-14 December 2014.

[22] Chaitanyan, C. and Raghuraman, S. (2013) A Study of Mechanical Properties of Sisal-Glass Reinforced Hybrid Composites. IJARSET, 6, 1-6.

[23] Zamri, M.H., Akil, H.M., Bakar, A.A., Ishak, Z.A.M. and Cheng, L.W. (2012) Effect of Water Absorption on Pultruded Jute/Glass Fiber-Reinforced Unsaturated Polyester Hybrid Composites. Journal of Composite Materials, 46, 51-61. http://dx.doi.org/10.1177/0021998311410488.

[24] Gujjala, R., Ojha, S., Acharya, S.K. and Pal, S.K. (2013) Mechanical Properties of Woven Jute-Glass Hybrid-Reinforced Epoxy Composite. Journal of Composite Materials.

[25] Abdellaoui, H., Bensalah, H., Echaabi, J., Bouhfid, R. and Qaiss, A. (2015) Fabrication, Characterization and Modelling of Laminated Composites Based on Woven Jute Fibres Reinforced Epoxy Resin. Materials and Design, 68, 104- 113. http://dx.doi.org/10.1016/j.matdes.2014.11.059