RESEARCH ARTICLE OPEN ACCESS

Effect of Chemical Treatment and Curing Parameters on Mechanical Properties of Natural Fiber Reinforced Polymer Matrix Composites-A Review

Rahul Shrivastava[1], Anisha Christy[2], Amit Telang[3] and R. S. Rana[4]
1, 2 Research Scholar, Department of Mechanical Engineering, MANIT, Bhopal, (M.P.), India
3, 4 Assistant Professor, Department of Mechanical Engineering, MANIT, Bhopal, (M.P.), India

ABSTRACT
A brief overview on natural fiber reinforced polymer composites is presented in this work. There is a growing trend to use non conventional and environmental friendly resources for engineering applications. In this scenario Natural fiber are offering a wide range of possibilities. Detailed and thorough study of structure of natural fiber indicates about its hydrophilic nature. Various types of chemical treatment techniques are used by researchers to increase the affinity of reinforcement and matrix .Studies shows that different factors like curing time, temperature, loading condition, fiber orientation etc. affect the properties of natural fiber composites. Lot of work has been carried out with the combination of different fibers and different polymers. Comparative data is presented on properties of different composite.

Keywords: Chemical treatment techniques, Curing time, Fiber orientation, Natural fiber

I. INTRODUCTION

Now- a- days there is a growing trend on using the non conventional type material in engineering and day to day processes. One of the promising materials, that are gaining popularity among scientist and researchers, is fiber reinforced polymer composite. The fiber-reinforced composite market was estimated at almost 1.04 million metric in 2002, and is expected to increase by 15% in volume [2].It is a promising substitute for conventional materials in different structural and engineering applications. It is expected that the usage of fiber/polymer composites will expand in the near future due to the advantages offered by these materials, i.e. high strength-to-weight ratio, manufacturability, and resistance to wear, corrosion resistant and impact strength [1]. In FRP composites there are two broad categories of fibers, Synthetic and natural fiber. Synthetic fibers offer better properties and costlier than natural fibers.

Fig 1 shows number of research papers published on the tribology of natural and synthetic fiber for the period of 2004 -2014. The given data revealed that extensive research work is carried out and still going on natural fiber polymer composites .In this work a comprehensive review is presented on the work had been carried out on natural fiber reinforced polymer composite.

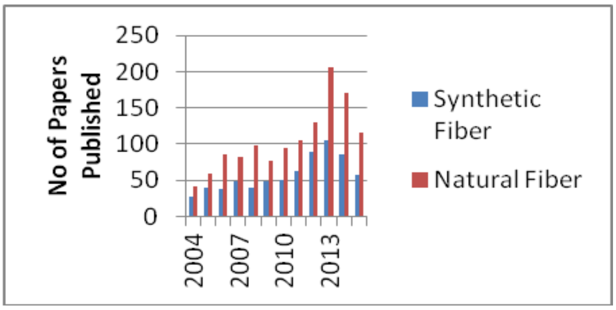

Fig. 1- Numbers of research papers published on the tribology of natural and synthetic fiber.

II. OVERVIEW OF NATURAL FIBER REINFORCED POLYMER COMPOSITES

Composites are presenting an option for researchers as they are advanced and adaptable engineering materials. This present work throws light on the work done on the natural fiber polymer composites.

2.1 NATURAL FIBER: CLASSIFICATION AND STRUCTURE

Natural fiber is lignocellulosic fiber. There are different natural lignocellulosic fibers obtained from different parts of plants. These fibers are jute, straw, Flax, hemp, wood, sugarcane, bamboo, grass , kenaf, sisal, coir, rice husks, wheat, barley, oats, kapok and mulberry etc. Among these, the most widely used plant fibers include cotton, sisal, jute, bamboo, wood, coir, kenaf and flax. Commonly used natural fibers are shown schematically in Fig 2. [3]. some researchers have studied the structure of natural fibers.

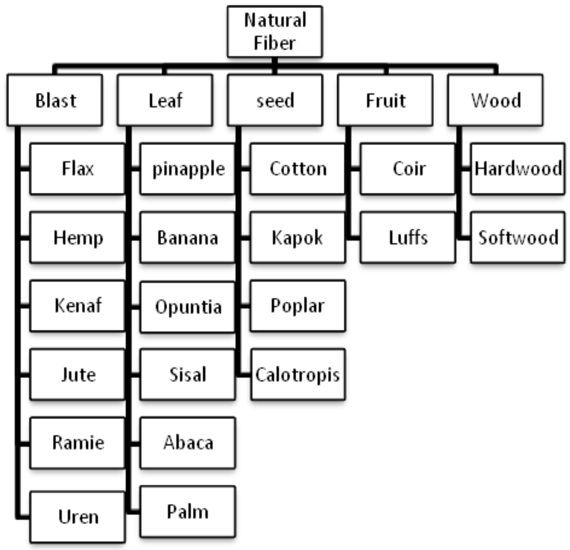

Fig. 2- Classification of natural fiber.

Table .1 shows chemical composition of different natural fibers like cellulose, lignin, hemicelluloses, wax etc.

Table .1- Chemical composition of different natural fiber [4] [5].

Fiber	Cellulose (%)	Lignin (%)	Hemicelluloses (%)	Pectin (%)	Wax (%)	Ref.
Coir	19.9-36.7	32.7-53.3	11.9-15.4	4.7-7	ND	24
Banana	48-60	14.4-21.6	102-15.9	2.1-4.1	3-5	25
Sisal	65.8	9.9	12	0.8	0.3	4
Jute	64.4	0.2	12	11.8	0.5	4
Pineapple	57.5-74.3	4.4-10.1	80.7	1.1	3.3	26
Cotton	82.7	28.2	5.7	5.7	0.6	4
Flax	64.1	2	16.7	1.8	1.5	4

A systematic representation of structure of natural fiber corresponding to important segment is shown in Fig 3 [5].

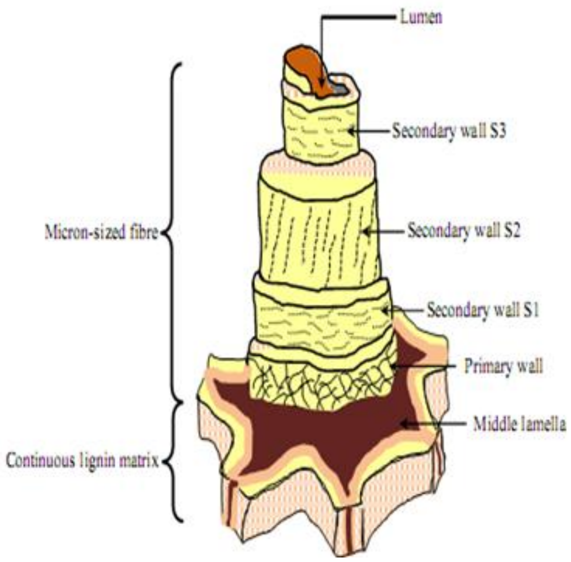

Fig.3 Typical Structure of a natural fiber. [5]

Thickness of Secondary wall S2, which have highest content of cellulose, is the deciding factor of the mechanical properties of a natural fiber. Hallow core of natural fiber allows it to contain lumen. The middle lamella, is responsible to firmly attach the whole micron-sized fiber onto it, is responsible for physical strength.

2.2. POLYMERS: THEIR TYPES AND COMPOSITION

Polymers are long molecular chain structure of carbon, hydrogen, and oxygen. Polymer are derived and produced from fossil fuel. Fig.4 shows the sequential chart of polymer production from raw materials [6].

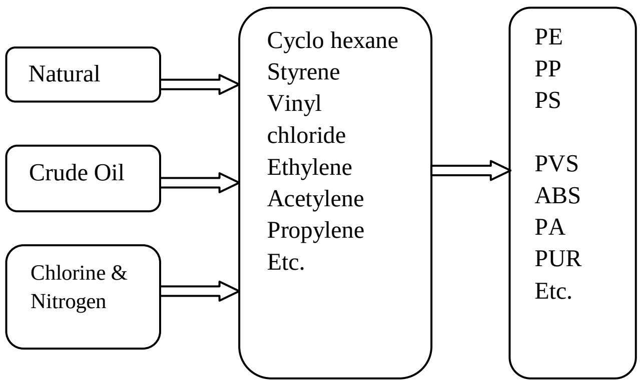

Fig.4- Production chart of polymer material from raw material.

Remark: PE-Polyethylene, PP-Polypropylene, PS-Polystyrene, PVC-Poly Vinyl Chloride.

Mainly Polymers are classified into two categories: Thermosetting and Thermoplastics. Thermosetting Polymers are reactive chemical materials .Application of heat initiates the cross linking of molecules and when curing is over complete solidification of polymer occur. These are brittle in nature. On the other hand thermoplastics are high molecular weight material which upon application of heat and pressure produces reversible cross linking chains. Thermoplastics are ductile and biodegradable.

2.3 DIFFERENT FACTORS AFFECTING THE PROPERTIES OF FIBER REINFORCED COMPOSITE

Combinations of various factors decide the mechanical properties of fiber reinforced composites. The fiber treatment, curing cycle, fiber volume, fiber orientation and effect of moisture absorption are the main parameters.

2.3.1 FIBER TREATMENT

As shown in Table no .1 cellulose is the main component of natural lignocellulosic fiber. Anhydro-d-glucose is the elementary unit of cellulose macro molecule. Anhydro-d-glucose contains three hydroxyls group (-OH). These hydroxyls form hydrogen bonds inside the macromolecule itself (intra-molecular) and also with hydroxyl groups from moist air. So it is evident that natural fibers have good affinity towards water hence hydrophilic. Various studies on natural fibers show that it can absorb 3-13% moisture [7].This affinity of fiber towards water leads to improper adhesion between fiber and polymer. The main component that is responsible for moisture absorption is hemicellulose. In addition, cellulose, lignin and also play a major role. Loss of strength occurs when cellulose undergoes through oxidation, hydrolysis and dehydration. Chemically treatment of fiber removes shell impurity, thus improving fiber-matrix adhesion. Chemical modification stimulates hydroxyl group to improve interlocking and bonding reaction between hydroxyl group and resin [8].Different chemical treatments along with alkali treatment have been performed on coir pith. Chemical treatments reduced the non-cellulosic content of coir pith and extend of removal varied for different types of treatments. AFM studies indicated a rougher surface morphology for chemically treated coir pith. Density of pith increased while water retention value decreased with treatment. The treatment gave an improved overall thermal stability for coir pith. Fig.5 shows the comparative data of weight retention of coir pith when subjected to different chemical treatment .These chemical treatments are Dicumyl peroxide treatment (DCP), Sodium hypochlorite treatment (NAH), Acrylic acid treatment (AA) Acetic acid treatment (ACA), Sulfuric acid treatment (SA) [9]. Significance of surface treatment on the coir reinforced polyester composites has been studied by some researchers. The coir fiber was subjected to alkali treatment, vinyl grafting, and bleaching before adding them with general purpose polyester resin. The mechanical characteristics like tensile strength, bending and impact strength were increased because of surface treatment [10]. These surface modification techniques makes fiber compatible to matrix material making natural fibers a substitute of synthetic fiber.

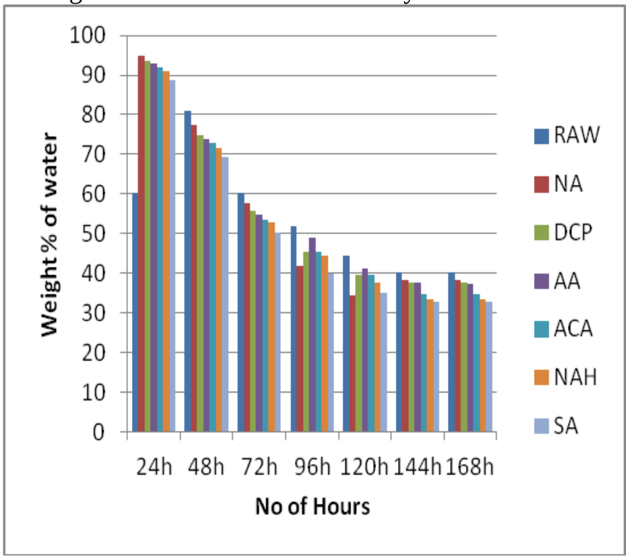

Fig.5 .comparative water retention by coir fiber subjected different surface treatment techniques.

2.3.2 CURE CYCLE

In a study the three main processing parameters that are time; temperature and Load are varied during the curing process. These variations help to control the vaporization of water during cross linking reactions. Properties of composite got decreased as water molecules vaporize forming voids. Lower amounts of voids are formed when high final pressure used at the point of matrix cure consolidation [11].

Table.2- Cure cycle for phenolic composites, using the highest pressure values at the last step of phenolic matrix curing process

Step	Time (min)/Temperature (°C)	Pressure ($kgfcm^{-2}$)				
		A	B	C	D	E
1	60/75	0	0	0	0	0
2	90/85	5.9	5.9	5.9	5.9	5.9
3	30/95	11.9	11.9	11.9	11.9	11.9
4	30/105	17.8	17.8	17.8	17.8	17.8
5	60/115	23.8	23.8	23.8	23.8	23.8
6	90/125	23.8	29.7	29.7	29.7	29.7
7	90/125	0	29.7	35.7	41.6	47.6

Based on above observations, the variation of impact strength of different samples are shown in fig.6

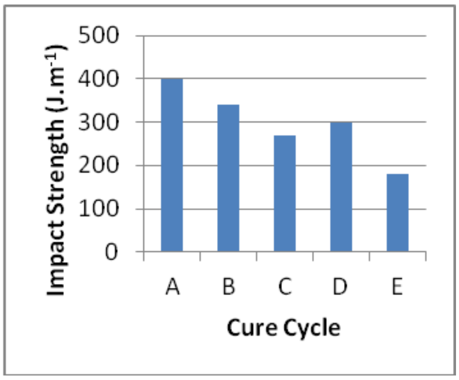

Fig. 6- Variation of impact strength of different samples.

2.3.3 FIBER VOLUME AND ORIENTATION

Weight percentage of fiber is an important factor in fiber reinforced composite polymers. Sisal /coir fiber epoxy polymer composite was fabricated and test results shows that on increasing fiber loading, mechanical properties increase in sisal fiber /epoxy polymer composite [13]. Fig.8 shows effect of fiber loading on tensile and flexural strength. Fiber orientation also has significant effect on the properties of composite. Test results shows that he tensile strength of composites with fibers in the parallel direction are 20-40% higher than those in perpendicular direction [12].

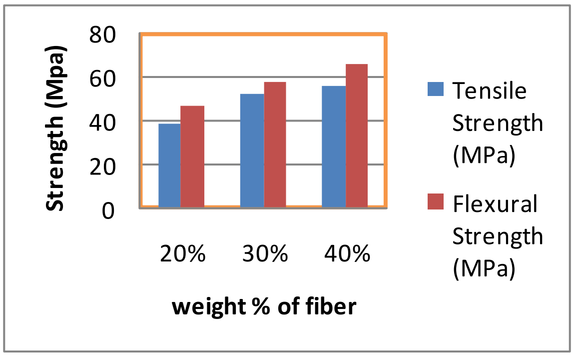

Fig.7-Effect of fiber content on tensile and flexural strength of sisal/coir epoxy composite

2.3.4. EFFECT OF MOISTURE ABSORPTION

Comparison has been made between tensile and flexural strength of wetted and non wetted sisal/coir hybrid composite. Tests revealed that there is a reduction of 9-14% of flexural strength due to moisture absorption and tensile strength decrease from 3-16% due to moisture [13]. Some researchers has summarized that natural fiber/polymer composites are sensitive to moisture and moisture exposure will cause them to lose their functionality. It is a reasonable explanation of decrement in properties [14].

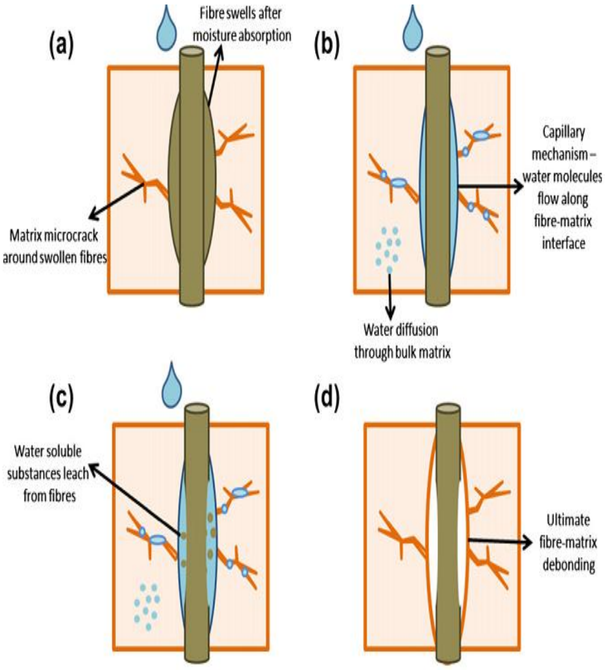

Fig.9- Effect of moisture on fiber – matrix interface [14].

2.4 MECHANICAL PROPERTIES OF DIFFERENT FIBER WITH DIFFERENT POLYMERS

In this part various properties like tensile strength, impact strength and flexural strength of different fiber/polymer combination have been reviewed. By hand layup method jute fiber epoxy composites was fabricated and studied for the physical and mechanical properties of the prepared composites. It has been concluded that the presence of voids in the composites adversely affect its mechanical properties [15]. The mechanical properties of jute fabric reinforced polyester composites has been studied by a group of researchers and it's been found that they have better strengths than those of wood based composites[16]. Dynamic mechanical analysis of natural fibers like sisal, palf (pineapple leaf fiber), oil palm empty fruit bunch fiber etc. in various matrices has been made and compared by researchers [17-18]. Polypropylene resin with Jute fiber composites gives better mechanical properties than Polypropylene resin with kenaf fiber composites [19]. A comparative study has been on different natural fiber (vakka, sisal, bamboo, and banana) with polyester resin [20]. With the variation in volume fraction different properties of the composite varied. Fig 10 and Fig. 11 shows the effect of volume fraction of fiber on specific tensile modulus and mean flexural modulus of various natural fiber composites.

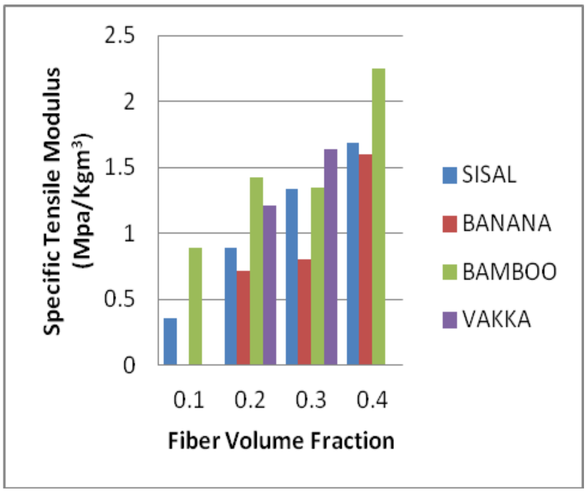

Fig.10- Volume fraction Vs specific tensile modulus of different natural fibers.

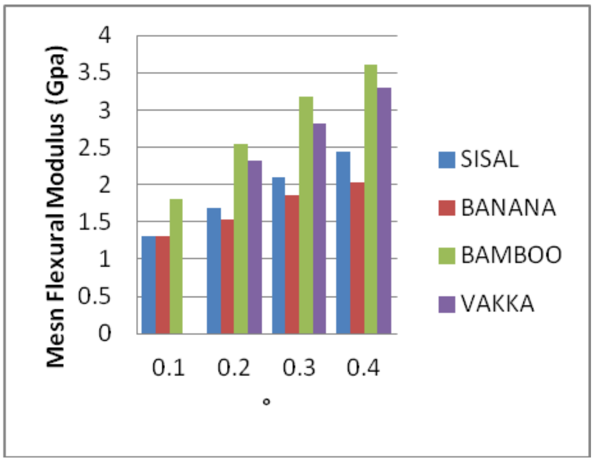

Fig.11- Volume fraction Vs and mean flexural modulus of different natural fibers.

Studies have been performed on mechanical, thermo physical and fire features of polyester composites reinforced with sansevieria fiber. It was observed that at maximum fiber content, the tensile and mechanical properties were increasing 2.55 and 4.2 times to that of neat resin respectively [21]. Coconut sheath fiber and epoxy resin were fabricated and then compared for mechanical properties and thermal degradation phenomena. A sound increase in mechanical property in treated coconut sheath fiber epoxy fiber than untreated category is noted [22]. Various researchers have studied natural fiber polymer composite with different fiber and polymer composition. Table.3 shows properties of different fibers with polypropylene resin.

Table.3- Various natural fibers /polypropylene composite

PolyPropylene	Wt% of fiber	Treatment	Tensile Strength (MPa)	Flexural Strength(MPa)	References
Jute	40	No	27	55	27
Flax	30	Yes	25	51	28
Sisal	40	No	34	25	27
Hemp	40	No	53	55	27
Kenaf	40	No	28	27	27
Coir	40	No	11	28	27

III. Conclusion

Natural fiber reinforced polymer composites offer a potential use in engineering fields like automobile, sports, medical, transportation, and construction and packaging industries. Natural fibers are cost effective, renewable source to modify the properties of polymer composite. Natural fiber polymer composite exhibits a substitution of synthetic fiber polymer composite .Though a lot of work is been performed to enhance the properties of NFRPC but still there is need of further work to improve the properties of natural fiber reinforced polymer composite.

REFERENCES

[1] Yousif B and El-Tayeb N.,"*Tribological evaluations of polyester composites considering three Orientations of CSM glass fiber using BOR machine*", *Applied Composite Material*, 2007; 14:105–16

[2] Business Communications Co. Inc, "*Composites: Resins, Fillers, Reinforcements, Natural Fibers and Nanocomposites*", Report number RP-178.

[3] Kozłowskiy R and Władyka-Przybylak M., "*Flammability and fire resistance of composites reinforced by natural fibers*", *Polymers for Advanced Technologies*, 2008;19: 446-453

[4] Bledzki A. "*Composites reinforced with cellulose based fibers*". *Progress in Polymer Science*, 1999; 24(2):221–74.

[5] Methacanon P, Weerawatsophon U, Sumransin N, Prahsarn C, Bergado DT. "*Properties and potential application of the selected natural fiber as limited life geotextiles*". *Carbohydrate Polymer*, 2010;82(4):1090–6

[6] Billmeyer FWJ. Textbook of polymer science. 3rd Ed. New York, NY: Wiley; 1984.

[7] Bledki AK, Reihmane S, Gassan J. J., "*Properties and modification methods for vegetable fibers for natural fiber composites*" *Applied Polymer Science* 1996;59:1329.

[8] Narendar.R, Dasan .K.P. "*Chemical treatments of coir pith: Morphology, chemical composition, thermal and water retention behavior*", *Composites*, 2014;56: 770–779

[9] Narendar.R, Dasan .K.P. "*Chemical treatments of coir pith: Morphology, chemical composition, thermal and water retention behavior*", Composites, 2014;56: 770–779

[10] Rout, J., Misra, M., Tripathy S. S., Nayak, S. K., & Mohanty A. K. "*The influence of fiber treatment on the performance of coir-polyester composites*". *Composites Science and Technology*, 2001; 61-(9):1303-1310

[11] Jackson D, Megiatto Jr., Cristina G. Silva, Elaine C. Ramires, Elisabete FrollinI. "*Thermoset matrix reinforced with sisal fiber: Effect of the cure cycle on the properties of the biobased composite"*, *Polymer Testing*, 2009; 28: 793–800.

[12] Kuruvilla Joseph, Romildo Dias Toledo Filho, Beena James, Sabu Thomas & Laura Hacker de Carvalho, "*A review on Sisal fiber reinforced Polymer composites*", *Revista Brasileira de Engenharia Agrícola e Ambiental*, Brasil, 1999; 3 (3): 367-379.

[13] C.Girisha, Sanjeevamurthy, S.Gunti Ranga, "*Sisal/Coconut Coir Natural Fibers – Epoxy Composites: Water Absorption and Mechanical Properties*". *International Journal of Engineering and Innovative Technology (IJEIT)*, 2012; 2(3).

[14] Azwa Z.N., Yousif B.F., Manalo A.C., Karunasena W., "*A review on the degradability of polymeric composites based on natural fiber*", *Materials and Design*, 2013; 47: 424–442.

[15] Mishra, V., & Biswas, S., "*Physical and Mechanical Properties of Bi-directional Jute Fiber Epoxy Composites*". *Procedia Engineering*, 2013; 51: 561-566.

[16] Gowda T. M, Naidu A. C. B, and Chhaya R,. "*Some Mechanical Properties of Untreated Jute Fabric-Reinforced Polyester Composites*", *Composites Part A: Applied Science and Manufacturing*, 1999; 30(3): 277-284.

[17] Joseph K, Thomas S, Pavithran C, "*Viscoelastic properties of short-sisal-fiber-filled low-density polyethylene composites: effect of fiber length and orientation*", *Materials Letters*, 1992; 15: 224-228.

[18] George J, Bhagawan S. S and Thomas S, "*Thermo gravimetric and dynamic, mechanical thermal analysis of pineapple fiber reinforced polyethylene composites*", *Journal of Thermal Analysis and Calorimetric*, 1996; 47(4): 1121-1140.

[19] Ahmed E. M, Sahari B, Pedersen P. "*Non-linear behaviour of unidirectional filament wound COTFRP, CFRP, and GFRP composites*". *Proceedings of World Engineering Congress, Mechanical and Manufacturing Engineering, Kuala Lumpur*; 1999: 537–43.

[20] Murali K R.Mohan, Rao.K. Mohana , Prasad A.V.Ratna , "*Fabrication and testing of natural fiber composites: Vakka, sisal, bamboo and banana*" , Materials and Design,2010; 31: 508–513.

[21] Ramanaiah, K., Prasad A. V Ratna., & Hema Chandra, "*Mechanical, thermophysical and fire properties of sansevieria fiber-reinforced polyester composites*". Materials & Design,2013; 49: 986-991.

[22] K. Suresh., Duraibabu, Subramanian K. "*Studies on mechanical, thermal and dynamic mechanical properties of untreated (raw) and treated coconut sheath fiber reinforced epoxy composites*". *Materials & Design*, 2014; 59:63-69.

[23] Paul W, Jan I, Ignaas V. "*Natural fibers: can they replace glass in fiber reinforced plastics? Composite Science Technology*, 2003; 63:1259–64.

[24] Mwaikambo LY, Bisanda ETN. "*The performance of cotton-kapok fabric polyester composites*". *Polymer Testing*, 1999; 18: 181–98.

[25] Mark .H.F, "*Fiber chemistry, handbook of fiber science and technology*": Volume I. In: Menachem Lewin, Eli M. Pearce, editors. New York: Marcel Dekker; 1985 (Journal of Polymer Science, Part C: Polymer Letters 1986; 24:486–487).

[26] Preethi P, Balakrishna MG. "*Physical and chemical properties of banana fiber extracted from commercial banana cultivars grown in Tamilnadu State*". *Agro technology*, 2013; 11:1–3

[27] Paul W, Jan I, Ignaas V. "*Natural fibers: can they replace glass in fiber reinforced plastics*", *Composite Science Technology*, 2003; 63: 1259–64.

[28] Cantero G, Arbelaiz A, Llano-Ponte R, Mondragon I. "*Effects of fibre treatment on wettability and mechanical behaviour of flax/polypropylene composites*". *Composite Science Technology* 2003(Jul.).; 63(9):1247–54