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Investigation of Mechanical Properties of Natural Fibers –A Review

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Abstract:-Natural fiber is a renewable resources and supplements for polymer based materials. The development of this composite material in natural fiber or environmentally friendly composites has been spread widely in our society. Natural fibers are one of the proficient materials where the synthetic materials have been replaced and this product relates for the application like less weight and energy conservation. The application of natural fiber reinforced polymer composites and natural-based resins for replacing existing synthetic polymer or glass fiber reinforced materials in huge. Automotive and aircrafts industries are more interested in developing different kinds of natural fibers, specifically on hemp, flax and sisal and bio-resins systems for their interior components. The main reason for making this as an attractive one is with High specific properties with lower prices of natural fiber composites.

I. INTRODUCTION

Natural fibers are proficient material which replaces the synthetic materials by relating its products for the less weight and energy conservation applications. The application of natural fiber reinforced polymer composites are natural-based resins for replacing existing synthetic polymer or glass fiber reinforced materials are in huge. Automotive and aircrafts industries are actively developing different kinds of natural fibers, mainly on hemp, flax and sisal and bio-resins systems for their interior components. High specific properties with lower prices of natural fiber composites make it an attractive for various applications.

The applications of natural fibers are developing in many sectors such as automobiles, furniture, packing and construction. This is mainly due to their advantages i.e. low cost, low weight, less damage to processing equipment, improved surface finish of moulded parts composite, good relative mechanical properties, abundant and renewable resources. Natural fibers are used in various applications such as building materials, particle boards, insulation boards, human food and animal feed, cosmetics, medicine and for other biopolymers and fine chemicals. The natural fibers that have moderate mechanical properties when compared to synthetic fibers like glass, carbon, kevlar etc., but the major disadvantage of natural fibers is high moisture sensitivity.

II. OVERVIEW OF NATURAL FIBER

Natural fibers such as flax, jute and hemp have been used by humans for thousands of years, back at least 7000 years in Egypt. The use of natural bras has gained substantial interest, where these fibers may be combined with thermoset or thermoplastic polymers to create natural fiber composites, which have been particularly identified for their sustainability attributes. Sustainability properties of natural fibers such as flax, jute and hemp include: renewable resources that absorb CO2 and retuning O2 to the environment short growth cycle times low energy production recyclable, biodegradable and low hazard manufacturing [1].

The exploitation of fillers materials such as fly ash and red mud along with natural fibers shows much interest in their researches. This is due to its greater improvement in mechanical properties, very less cost and easy accessibility in

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the industrial market. Saxena et al.illustrates that usage of the industrial waste along with the natural fiber such as the addition of the filler material such as fly ash and red mud are the enhancement of the mechanical property for the composite materials[2].

Composite are combination of two materials, one of the material is reinforcing phase composite material such as polymer composite ,cement and metal matrix composite polymer matrix composite are mostly commonly used composites in which different reinforcing material are taken from resin in matrix. Polymer-resin is classified in two types thermoplastic and thermo-set in which fiber like natural and manmade fiber used for different application. Composites are now commonly been used for rehabilitation and strengthening the pre-existing structures that have been retrofitted to make them seismic resistant or to recover the damage caused by seismic activity. Unlike conventional materials like steel, the properties of this composite material can be designed in consideration of structural aspects. Composite materials are mostly, classified into three groups on the basis of matrix material. They are

• Metal Matrix Composites (MMC)

• Ceramic Matrix Composites (CMC)

• Polymer Matrix Composites (PMC) [3].

The applications of natural fibers are developed in industries such as automobiles, furniture, packing and construction. This is mainly due to their advantages compared to synthetic fibers, i.e. low cost, low weight, less damage to processing equipment, improved surface finish of moulded parts composite, these composites have good relative mechanical properties, abundant and renewableresources [4].

Aspects	Property	Natural fibers	Synthetic fibers
Technical	Mechanical properties	Moderate	High
	Moisture sensitivity	High	Low
	Thermal sensitivity	High	Low
Environmental	Resource	Infinite	Limited
	Production	Low	High
	Recyclability	Good	Moderate

Table 1-Comparision between Natural Fibers and Synthetic Fibers

The inverse thermal analysis of heat conduction is carried out to estimate the in-plane thermal conductivity of composites. Numerical simulations are performed to determine the optimal configuration of the heating system to ensure a unidirectional heat transfer in the composite sample. Composite plates are made of unsaturated polyester resin and unidirectional glass fibers were been fabricated by injection to validate the methodology. A heating and cooling cycle is been applied at the bottom and top surfaces of the sample [5].

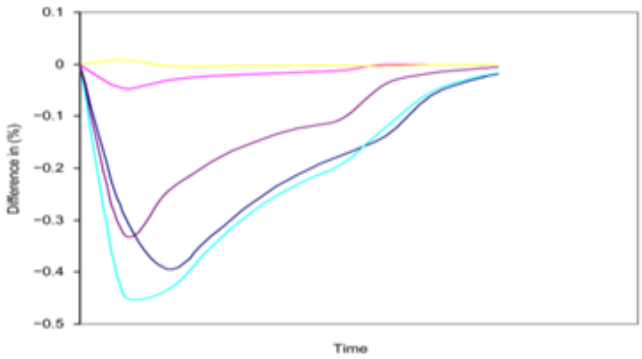

Figure 1- Evolution of Temperature Differences in Time Between Thermocouples Located At The Same Level in the Composite Specimen.

A recent study on PLA composite was carried out by Ochi where in his investigation, the unidirectional biodegradable composite materials were fabricated from kenaf fibers and PLA which showed that tensile and flexural strengths of 223 MPa and 254 MPa respectively were achieved. The petroleum based product creates the environmental problems during disposal and emission which increases in development of natural fiber composites for low and medium load applications. Many comparisons between different types of natural fibers commonly used in the automotive sector in addition is the date palm [6-8].

Level 1 Category	Level 2 Property/Characteristic	Level 3 Criteria
Natural Fibers Properties	Physical	Density, Surface topology, Texture, Form and geometry (Fiber's Diameter, Fiber's Length, Length/Diameter Ratio, Microfibrillar Angle), Coefficient of thermal expansion, Thermal conductivity, Specific heat, Electrical conductivity, Sound absorption coefficient.
	Chemical and Biological	Chemical composition (cellulose, lignin, etc.), Batch quality, Consistency of batch quality, Availability, Resource shortage, Planting limitations, Odder emission, Burning rate.
	Mechanical	Elastic modulus, Shear modulus, Poisson's ratio, Yield strength, Elongation to break, Specific modulus of elasticity, Specific yield strength, Specific shear modulus.
	Technical	Processing knowledge and time, Friendly processing, Processing energy consumption, Processing time, Processing cost, Transferring cost, Raw fiber cost, Cost of energy input (fiber separation, fertilizers, machines, etc.)
	Environmental	Eco-friendly, Government support, Bio-degradability, Social positive view.

Table 2-Criteria Affect the Selection of Products Made from Natural fiber Composite Materials on fiber Level.

The tensile strength of starch foams and sometimes the deformation at break were also improved by the addition of different types of fiber, such as softwood, aspen, jute and flax fibers. However, high price and limited properties of the fully degradable polymer hinder the diversity of the usage. All composites models contain the young's modulus or the tensile strength of the reinforcing fibers. Short natural fibers have gained increasing interests in the past decades due to their exceptional advantages over traditional man-made fiber reinforced composites [9-12].

In this point of view, a brief review has been carried out to make use of natural fibers (such as abaca, banana, bamboo, cotton, coir, hemp, jute, pineapple, sisal etc.) abundantly available in India. Glass Fiber Reinforced Polymers are mixing with natural fibers to increase Engineering and Technology applications. Compressive behavior in an elastic region and post collapse behavior of NFC tubes [13-15].

Multifunction composites have been verified as an enticing candidate for various applications including wearable electronics and actuating device. Natural fiber composites are gaining interest in manufacturing because they address some of the environmental problem of traditional composites. Natural fibers have employed in many domains, such as transportation, textile and building industries. Materials from numerous sources have been studied ranging from different common agriculture waste to industries by product and from cultivation plant to grasses and weed [17-20].

Sample name	PCL (wt%)	Hemp fibres (wt%)	BDF (wt%)	Molar ratio BDF/PCL (10^{-3})	Purpose & analysis
PCL	100	0.0	0.0	0.0	Reference
PCL-BDF 1.1%	98.9	0.0	1.1	2.8	Threshold
PCL-BDF 2.3%	97.7	0.0	2.3	6.0	Threshold
PCL-BDF 4.5%	95.5	0.0	4.5	12.0	Threshold
PCL-BDF 9%	91.0	0.0	9.0	25.3	Threshold
PCL-Hemp 4.5%	95.5	4.5	0.0	–	Microstructure
PCL-Hemp 7.1%	92.9	7.1	0.0	–	Microstructure
PCL-Hemp 19.8%	80.2	19.8	0.0	–	Microstructure
PCL-Hemp 22.5%	77.5	22.5	0.0	–	Microstructure

Table 3-Composites Made Of PCL, BDF and Hemp Fibers At Different Concentrations.

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Natural fibers cost low and reduce in density when compared to glass fibers. The strength of natural fibers is not as great as glass, the specific properties are comparable. Currently natural fiber composites have two issues that need to be addressed: resin compatibility and water absorption.The true mechanisms of gecko foot-hairs adhesion and engineers have attempted to fabricate synthetic fiber adhesives, achieving even higher adhesion strengths than the real gecko footpads. However, high adhesive strength is the only one criterion in matching the performance of gecko foot-hairs we must also consider repeatability, directionality, reliability, and efficiency [22-25].

Several low cost composites composed of polyurethane are renewable natural fibers were developed toanalyze for their mechanical and physical properties. Polymer composites were fabricated with poly-lactic acid and cellulosic natural fibers combining the wet-laid fiber sheet forming method with the film stacking composite making process. The stabilization of soils with natural polymers and fibers to produce a composite, sustainable, non-toxic and locally sourced building material. This experiment focused on the surface treatment of natural fibers and the use of nano-cellulose, a natural nanofiber, for their application in composite materials. The tensile, impact and free vibration properties of sisal or coconut fiber hybrid-reinforced unsaturated polyester composites [26-30].

Abaca-banana-glass composites have been fabricated and its mechanical properties were analyzed. Matrix material used is a phenolic resin of ortho-phthalic acid. The work glass fiber reinforced polymers are mixing with sisal and various fiber lengths (5, 10, 15,20mm) to increase engineering and technology application. The low cost polymer composite using brown grass flower broom reinforcement is been prepared. The preparation polymer composite have low porosity, homogeneous surface structure, and the greatest interface bonding.These properties of natural fiber based on composite building materials that is applicable for hot and humid climate regions [31-34].

III. LITERATURE REVIEW

M.R. Bambach investigates the study of the reliable and predictable, albeit modest, mechanical behavior of natural fiber composite structures of flax, jute and hemp in pure compression. With appropriate attention to fiber and resin design and structural geometry, natural fiber composites may prove a viable alternative to traditional building materials in the future. The initial findings of structural properties and design methods show promise for residential and light commercial building applications, however further research is necessary[1].

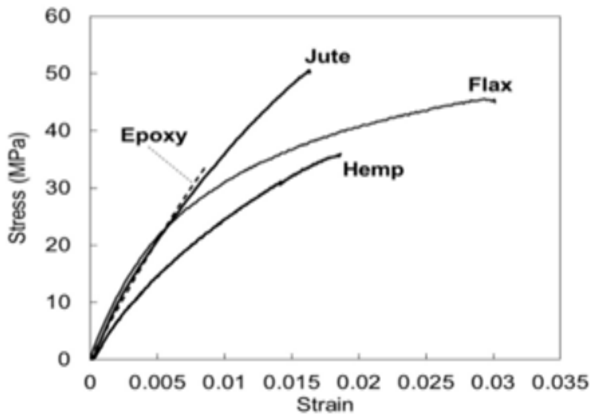

Figure 2-Stress-Strain Curves of the Neat Epoxy and the fiber Resin Composites.

P.Ganeshan, K.Rajainvestigates the study of theRed mud is used as a filler material to fabricate polymer matrix composites successfully. By the addition of red mud, it shows that the potential applicability in the wide area of application for making low cost composites and also environmental related issues are reduced much more. By the addition of the red mud in the polyester composite from the result it clearly observed that the mechanical properties such as flexural strength and impact strength of the polyester composites have considerably increased [2].

C.Kandeepan,P.Ganeshan, K.Rajainvestigates the study of the newly extracted madar fiber is extracted from stem of the plant by manual process. It finally is subjected to investigation of mechanical properties such as tensile strength, compressive strength, impact strength, and flexural strength. Thus the madar fiber is renewable and is found all over the world this fiber can be used to prepare composite material for automobile [3].

A. Mechanical Properties of Madar Fiber

Bio fibers had recently become eye catching for the scientists and engineers due to its high mechanical strength. In this present work, newly identified madder fiber is used for making composite material the fiber is extracted from the stem by manual process. The fiber is separated into small parts and then it is mixed with polyester resin.

a). Tensile Test

Madar fiber finally is subjected to investigation of mechanical properties such as tensile strength, compressive strength, impact strength, and flexural strength. The tensile strength value is better at 60% resin and 40% fiber is 38.4Mpa.

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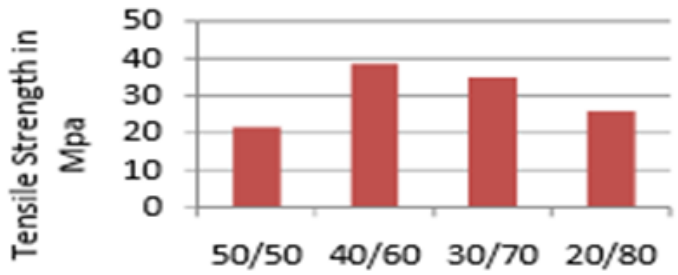

Figure 3-Tensile Strength Table

Fiber to resin ratio	Tensile strength
50/50	21.3
40/60	38.4
30/70	34.82
20/80	25.72

Figure 4-Tensile Strength

b). Impact Testing

The impact strength value of the madar fiber value increase from 20% fiber plate to 40% fiber plate and then suddenly decrease at 50% fiber and 50% resin plate. This shows that impact strength value better at 60% resin and 40% fiber plate. The impact strength value is better at 60% resin and 40% fiber is 2.722.

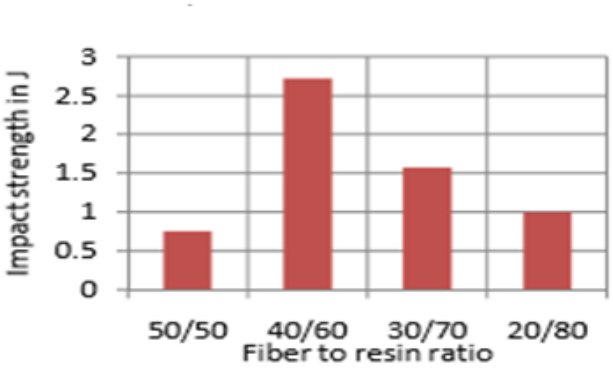

Figure 5-Impact Strength

Fiber to resin ratio	Impact strength
50/50	0.76
40/60	2.722
30/70	1.576
20/80	1.001

Table 6-Impact Strength

M.R.Sanjay, G.R.Arpitha, L.Laxmana Naik, K.Gopalakrishna, B.Yogeshainvestigates the study of the applications of natural fiber and its composites. It concludes that the natural fiber composites form one of the emergent areas in material science that makes awareness for use in various applications [4].

Bassam Assaf, Vincent Sobotka, Francois Trochu investigates the study of the inverse thermal analysis was conducted to determine the in-plane thermal conductivity of composite specimens. The mold that devised initially for thickness measurements can be successfully used to measure the in-plane thermal conductivity of composites. This mold has an adjustable cavity depth and is equipped with heating cartridges and cooling channels to control the temperature. Two pressure sensors monitor the pressure of the sensor during the injection. Numerical simulations were carried out to verify a unidirectional heat transfer takes placed in the cavity during the experiments. An experimental protocol was been followed to inject planar composite specimens [5].

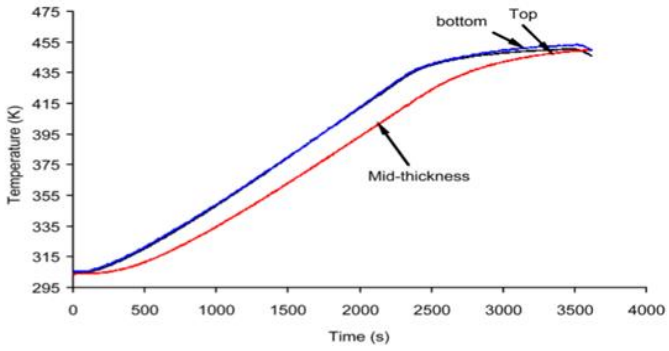

Figure 7-Temperature Evolution of the Three Thermocouples through the Thickness of the Cured Resin During Heating.

J.Sahari, S.M.Sapuaninvestigates the study of theNatural fiber reinforced biodegradable polymer composites appear to have very bright future for wide range of applications. These bio-composite materials with various interesting properties may soon be competitive with the existing fossil plastic materials [6].

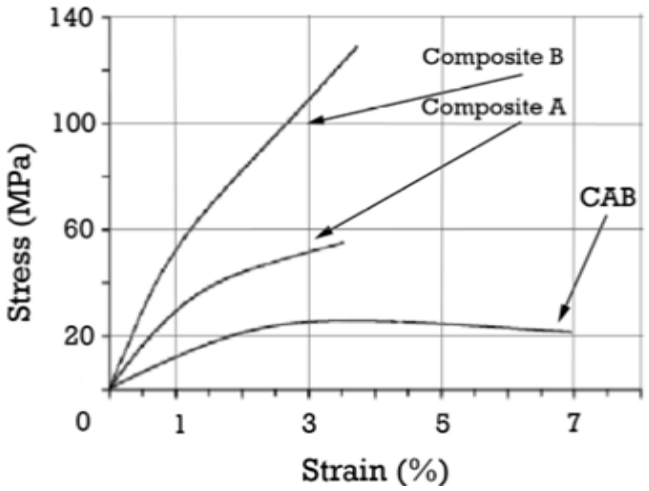

Figure 8- Stress and Strain Test of Tensile Test of Cellulose Acetate Butyrate.

Murugan Rajesh, Jeyaraj Pitchaimani investigates the study of the influence of nature of fiber yarn (conventional twisted straight yarn and braided yarn) and fiber yarn orientation on mechanical behavior such as tensile, flexural and impact properties have been investigated. Results reveals that braided yarn jute woven fabric enhances the mechanical properties of composite compared to conventional woven jute woven composite [7].

Composite	Density ($g \cdot cm^{-2}$)		Void (%)
	Experimental	Theoretical	
JC	1.208	1.190	1.51
IPC	1.192	1.174	1.55
JB	1.233	1.209	1.98
IPB	1.227	1.210	1.40
JSR	1.166	1.130	2.61
SRH	1.192	1.151	3.57

Table 4: Density of Different Composites.

Faris.M, AL-Oqla, S.M.Sapuaninvestigates the study of the work was able to categorize and tabulate the criteria that affect the NFC material in distinguished levels for first time. Adopting DPF in automotive industry will be an added value stop towards enhancing the sustainability and productivity [8].

Jean-Charles Benezet, Andrea Stanojlovic-Davidovic, Anne Bergeret, Laurent ferry, Alain Crespy investigates the study of the fiber nature as well as water absorption rate are the main factors modifying the mechanical strength of the composites. The mechanical properties were affected by both relative humidity of storage and foam formulation [9].

Mei-po Ho, Hao Wang, Joong-Hee Lee, Chun-Kit Ho, Kin-tak Lau, Jinsong Leng, David Huiinvestigates the study of the natural fiber can be classified as plant based and animal based. There is still uncertain on which type of manufacturing process that is suitable for producing these composites as their composites as their material and mechanical character are different as compared [10].

Axel Nechwatal, Klaus-Peter, Thomas Reubmanninvestigates the study of the manufacturing of long fiber granules requires lower energy than conventional process because only the surface of the granule is molten [11].

Yihui Pan, Zheng Zhong investigates the study of the experimental results of short sisal fiber reinforced polypropylene; the present theoretical model gives a pretty good prediction of the evolution of the internal variable and a reasonable estimation of the degraded young's modulus of SNFRCs [12].

Sanjay.M.R, Arpitha.G.R, B.Yogeshainvestigates the study of the natural fiber reinforced composites are used in many engineering applications, because of its superior properties such as specific strength, low weight, low cost, fairly good mechanical properties, non-abrasive, eco-friendly and bio-degradable characteristics [13].

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	Natural fibres	Glass fibres
Density	Low	Twice that of natural fibres
Cost	Low	Low, but higher than NF
Renewability	Yes	No
Recyclability	Yes	No
Energy consumption	Low	High
Distribution	Wide	wide
CO_2 neutral	Yes	No
Abrasion to machines	No	Yes
Health risk when inhaled	No	Yes
Disposal	Biodegradable	Not biodegradable

Table 5-Comparison between Natural and Glass Fibers

Bartosz.T.Weclawski, Mizi Fan, David Huiinvestigates the study of the filament winding technologies have been developed for the production of 3D component made with natural fiber yarns. The development machine and process were able to formulate the structure of the NFC tubes with various structure designs [14].

Sweety Shahinur, AMM Sharif Ullahinvestigates the study of the uncertainty associated with the material properties of a natural material called jute fiber. In particular, we have determined the density of jute fibers, and have performed tensile tests to determine the tensile strength and modulus of elasticity of raw and treated jute fibers having different lengths collected from the top, middle, and bottom segments of the whole jute plant fiber [15].

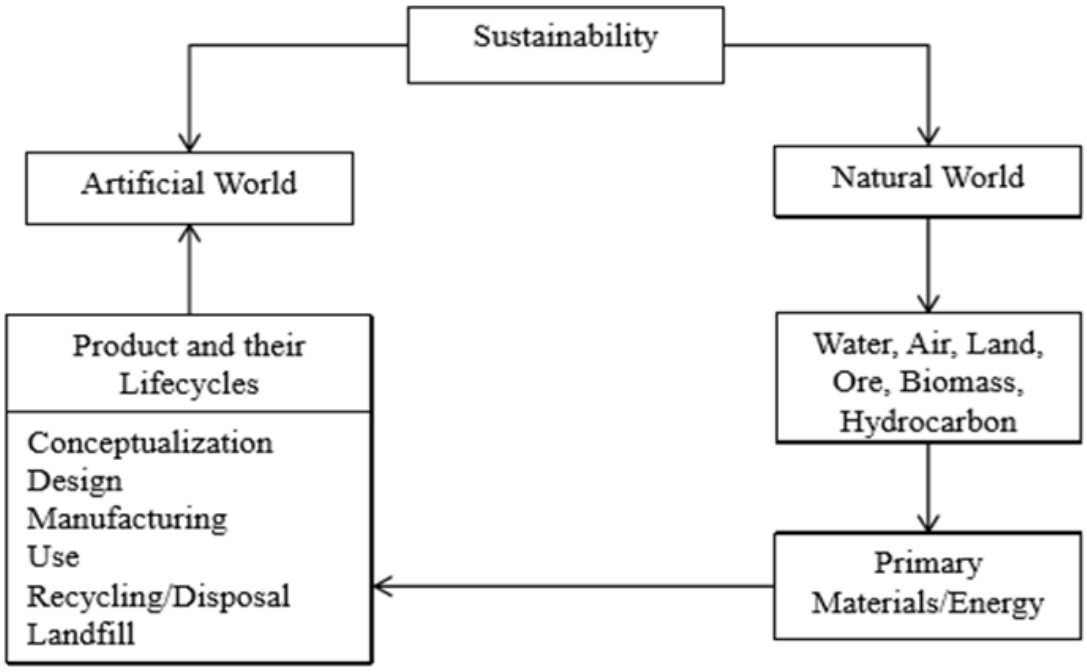

Figure 9-Sustainability of Product Lifecycle.

J.P.Torres, L.J.Vandi, M.Veidt, M.T.Heiztmanninvestigates the study of the statistical database on the database on the tensile properties of natural fiber reinforced composites laminates [16].

Li Ding, Shouhu Xuan, Jiabin Feng, Xinglong Gong investigates the study of the development of multifunctional MCF sensor by combining commercial latex yarn, AgNWs and PDMS into a coaxial structure [17].

Antoine Gallos, Gabriel Paes, David Legland, Florent Allais, Johnny Beaugrandinvestigates the study of the accuracy, strengths and limitation of the original proposed method by confocal raman imaging and image analysis. PCL and hemp fibers after extrusion get injection moulding [19].

Ajjima Nopparut, Taweechai Amornsakchaiinvestigates the study of the using the PALF treated with NaOH solution further improvement in these properties can be obtained [20].

Ning Pan, M.P.Westman, S.G.Laddha, L.S.Fifield, T.A.Kafentzis, K.L.Simmons investigates the study of the specific properties of Kenaf were less than that of the glass composites. This is primarily explained by the interface between the Kenaf and the vinyl ester resin [22-23].

Jiho Song, Yigit Menguc, Metin Sitti investigates the study of the method of fabricating large arrays of gecko-inspired microfibers with mushroom-shaped tip endings through the DRIE process coupled with soft polymer molding. The present process and demonstrated that our microfiber arrays had a greatly improved repeatability of adhesion, retaining 80% of their attachment strength after 1000 loading cycles [24].

L.Q.N.Tran, T.Nguyen, C.A.Fuenter, T.Truong Chi, A.W.Van Vuure, I.Verpoertinvestigates the study of the elementary fiber is built up by two main cells which consists of bundles of microfibers aligned in a high angle to the fiber axis. Coir fiber appears to have porosity at 22-30% [25].

Guilherme Piovezan Otto, Murilo Pereira Moises, Gizilene Carvalho, Andrelson Wellington Rinaldi, Juliana Carla Garcia, Eduardo Radovanovic, Silvia Luciana Favaroinvestigates the study of the foams developed in this work are commercially viable and sustainable alternatives to conventionally produced polyurethanes composites as the lignocellulosic fiber used are both low cost and biodegradable [26].

Yicheng Du, Tongfei Wu, Ning Yan, Mark T.Kortschot, Ramin Farnoodinvestigates the study of the pulp fiber showed superior modulus and strength reinforcement effect on the PLA matrix by combining a wet-laid fiber sheet forming process with the conventional composites fabrication methods [27].

C.Galan Marin, C.Rivera Gomez, J.Petricinvestigates the study of the characteristics of clayey soils stabilized with alginate and reinforced with sheep wool fiber. On the basis of test results they obtain five different stabilized soil mixtures [28].

Juliana Cruz, Raul Fangueiroinvestigates the study of the surface treatment of natural fiber has been the subject of interest for numerous researches in order to fully utilize the advantages of natural fibers in composites material in composites material and to successfully utilize them in various industrial application [29].

J.B.Sajin, R.Sivasubramanian investigates the study of the influence of moistures on young's modulus suggests that the fibers mechanical strength has decreased by the addition of coconut fiber density of the composites has increased [30].

H.Venkatasubramanian, S.Raghuramaninvestigates the study of the natural fibers like abaca, banana were reinforced with orthophthalic acid resin and its mechanical properties were analyzedat a volume fraction of 0.4 and 0.5 respectively [31].

Ashish Kumre, R.S.Rana, Rajesh Purohit investigates the study of the mechanical properties of different variation in fiber length of sisal epoxy composites, it has insufficient force transfer from epoxy to the fiber because of poor adhesion between fiber and matrix [32].

Jyoti Prakash Dhal, S.C.Mishrainvestigates the study of the void fraction of the composites increases slightly with the increase in the reinforced content. It might be due to the presence of pores or cavities in the fiber [33].

Pusit Lertwattanaruk, Anchisa Suntijittoinvestigates the study of the natural fiber cement sheets made of cement mortar containing coconut coir fiber and oil palm fiber yielded the comparable effects in the physical and thermal properties [34].

IV. CONCLUSION

The present situation has demonstrated the reliable and predictable, mechanical behavior of natural fiber composite structures such as flax, jute and hemp in pure compression. Red mud is used in filler material to fabricate polymer matrix composites successfully.

It finally states to the investigation of mechanical properties such as tensile strength, compressive strength, impact strength, and flexural strength. The natural fiber composites form one of the largest areas in material science that makes awareness for use in various applications.

The newly extracted madar fiber is extracted from the stem of the plant in manual process.The tensile strength value is better at 60% resin and 40% fiber is 38.4 Mpa. The compressive

strength is better at 60% resin and 40% fiber is 45 Mpa. The flexural strength value is better at 60% resin and 40% fiber is 45 Mpa. The impact strength value is better at 60% resin and 40% fiber is 2.722.Natural fiber reinforced biodegradable polymer composites seems to have a very bright future for larger applications. These bio-composite materials have various interests in properties that are competitive with the existing fossil plastic materials.These mechanical and physical properties of natural fibers have varies form of fibers.

Natural fiber reinforced composites most commonly used in many engineering applications, because of its superior properties such as specific strength, low weight, low cost, good mechanical properties, non-abrasive, eco-friendly and bio-degradable characteristics. Natural fibers with GFRP can improve their properties and used as an alternative material for glass fiber reinforced polymer composites material.

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