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Investigation of Mechanical Properties of Biodegradable Composite – A Review

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***Abstract*— In recent years, there has been a marked increase in interest in biodegradable materials for use in packaging, agriculture, medicine, and other areas. In particular, biodegradable polymer materials (known as biocomposites) are of interest. Polymers form the backbones of plastic materials, and are continually being employed in an expanding range of areas. As a result, many researchers are investing time into modifying traditional materials to make them more user-friendly, and into designing novel polymer composites out of naturally occurring materials. A number of biological materials may be incorporated into biodegradable polymer materials, with the most common being starch and fiber extracted from various types of plants. The belief is that biodegradable polymer materials will reduce the need for synthetic polymer production (thus reducing pollution) at a low cost, thereby producing a positive effect both environmentally and economically. This paper is intended to provide a brief outline of work that is under way in the area of biodegradable polymer research and development, the scientific theory behind these materials, areas in which this research is being applied, and future work that awaits.**

***Index Terms*— Natural Fiber, Biodegradable Composite, Mechanical Properties.**

I. INTRODUCTION

The interest in using natural fibers such as different plant fibers and wood fibers as reinforcement in plastics has increased dramatically during last few years. With regard to the surrounding aspects it would be very interesting if natural fibers could be used instead of glass fibers as reinforcement in some structural applications. Natural fibers have many advantages compared to glass fibers, for example they have low density, and they are recyclable and biodegradable. Additionally they are renewable raw materials and have relatively high strength and stiffness. Their low-density values allow producing composites that combine good mechanical properties with a low specific mass. In tropical countries fibrous plants are available in abundance Fiber reinforced polymer composites have many applications as a class of structural materials because of their ease of fabrication, relatively low prize and higher mechanical properties compared to polymer resins. These composites are considered as replacements for metal materials where the association of metallic fiber with polymeric matrix is attractive material for electronic packaging applications. The combination of reinforcement with high thermal conductivity embedded in a resin matrix with low thermal conductivity isdesirable to dissipating the heat flux for electronic packaging components. Studies on the mechanical properties ofshort fiber reinforced polymer composites have shown that both fiber length distribution and fiber orientation distribution play very important role in determining the mechanical properties. Natural fiber composites combine plant derived fibers with a plastic binder. The natural fiber components may be wood, sisal, hemp, coconut, thread, kenaf, flax, jute, abaca, banana leaf fibers, Bamboo, wheat straw or other fibrous material. The advantages of natural fiber composites include lightweight, low-energy production, and environmental friendly. The use of natural fibers reduces weight by 10% and lowers the energy needed for production by 80%, while the cost of the component is 5% lower than the comparable fiber glass-reinforced component.[1]

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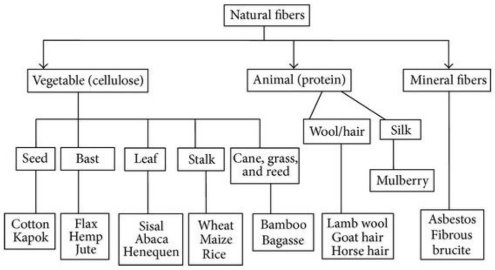
II. NATURAL FIBER

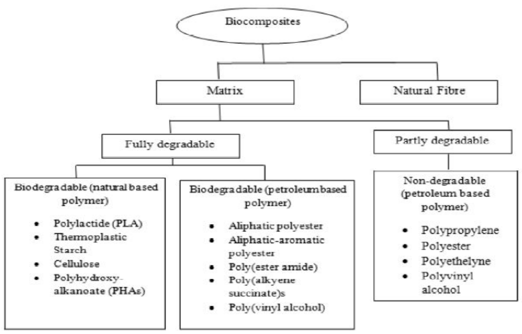
Natural fibers are made from plant, animal and mineral sources. As aforementioned, with the increasing global energy crisis and ecology risk, plant-based fiber-reinforced polymer composites have attracted much interest owing to their potential of serving as alternatives for artificial fiber composites, like glass and carbon. Although the strength of such fibers (more than one type) are general lower than that of the traditional advanced composites, in certain extent, the strength of plant-based fiber-reinforced composites is sufficient enough for domestic or household plastic products. Many attempts have been done in the past few years on using jute, bamboo, sisal, coir, hemp, flax, pineapple leaves, etc., for reinforcing different kinds of thermoplastic and thermoset polymers to form green composites.[2]Apart from the plant-based fibers, animal-based fibers become other alternatives for producing biodegradable, biomedical and bio-resorbable composite materials for bioengineering and orthopaedic applications. The content of these fibers are mainly made by proteins, like wool, spider and silkworm silk. The enhanced environmental stability of silk fibers in comparison to globular proteins is due to the extensive hydrogen bonding, the hydrophobic nature of much of the protein, and the significant crystallinity.[2]



Classification of Natural Fiber[3],[4]

III. BIODEGRADABLE COMPOSITE (BIOCOMPOSITE)

Biocomposite is a composite material formed by a matrix (resin) and a reinforcement of natural fibers. The matrix phase is formed by polymers derived from renewable and nonrenewable resources. The matrix is important to protect the fibers from environmental degradation and mechanical damage, to hold the fibers together and to transfer the loads on it.In addition, biofibers are the principal components of biocomposites, which are derived from biological origins, for example fibers from crops (cotton, flax or hemp), recycled wood, waste paper, crop processing by products or regenerated cellulose fiber (viscose/rayon).The interest in biocomposites is rapidly growing in terms of their industrial applications (Automobile, Railway coach, Militry Application, Construction and packaging) and fundamental research, due to its great benefits (Renewable, cheap, Recyclable and Biodegradation).[5]



Classification of Bio composites[6]

IV. LITERATURE REVIEW

M.Sakthivei et al [1]They focuses on the fabrication of polymer matrix composites by using natural fibers like coir, banana and sisal which are abundant nature in desired shape by the help of various structures of patterns and calculating its material characteristics(Hardness number,% gain of water, Density and Impact) by conducting tests like Hardness test, water absorption test, impact test, density test, and their results are measured on sections of the material and make use of the natural fiber reinforced polymer composite material for automotive seat shell manufacturing. Polymer matrix composite contains the various natural fibers as the reinforcement phase was successfully fabricated.

Hardness Test Results: The Rockwell hardness number represents the additional depth to which a test ball or sphere conical penetrator is driven by a heavy (major) load beyond the depth of a previously applied light(minor) load. Top hardness numbers that are obtained from hard materials indicate a shallow indentation while low numbers found with soft materials indicate deep indentation. The increment of penetration depth for each point of hardness on the Rockwell mount is 0.00008 inch.

Table 1.Tabulated Readings of Rockwell Hardness Number[1]

Sr. No	Polymer Matrix Composite	Intender used	Load in Kg	RNH
1	Coir	Diamond Indenter	150	36HR_c
2	Banana			63HR_c
3	Sisal			54HR_c
4	Coir	1/16 Ball Indenter	100	76HR_c
5	Banana			57HR_c
6	Sisal			92HR_c

Water Absorption Test Result: Water absorption is used to determine the amount of water absorbed under specified conditions. Factors affecting water absorption include: type of plastic, additives used, temperature and length of exposure. The data sheds light on the performance of materials in humid.

Table 2.Water Absorption Test Result [1]

Polymer Matrix Composite Material	Mass Before Test (g)	Mass After Test (g)	(%) Gain of Water
Coir	9.141	9.150	0.09
Banana	7.815	7.823	0.10
Sisal	7.531	7.535	0.05

Density Test Result : Density is the term used to describe the relationship between the weight of the substance and its size. Density is a physical property of every substance, and different substances have different densities. Density can be measured in a variety of units, including grams per centimeter and pounds per cubic foot.

Table 3.Density Test Result [1]

Polymer Matrix Composite	Mass(m) (Kg)	Volume(v) ($10^{-4}m^3$)	Density(ρ), m/v (Kg/m^3)
Coir	0.386	2.99625	1288
Banana	0.330	2.99625	1101
Sisal	0.346	2.99625	1155

Impact Test Result : The Charpy impact test, also known as the Charpy V-notch test, is a standardized high strain rate test which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's toughness and acts as a tool to study temperature-dependent ductile-brittle transition. It is widely applied in industry, since it is easy to prepare and conduct and results can be obtained quickly and cheaply. manufacturing of automotive seat shells among the other natural fiber combinations.

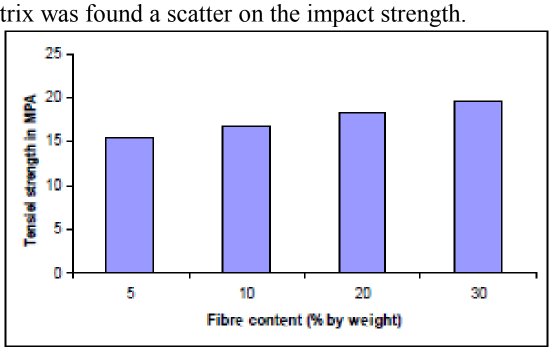
Table 4.Impact Test Result [1]

Sample	Polymer Matrix Composite Material	Impact Energy in Scale(Joule)
1	Coir	4
2	Banana	5
3	Sisal	4

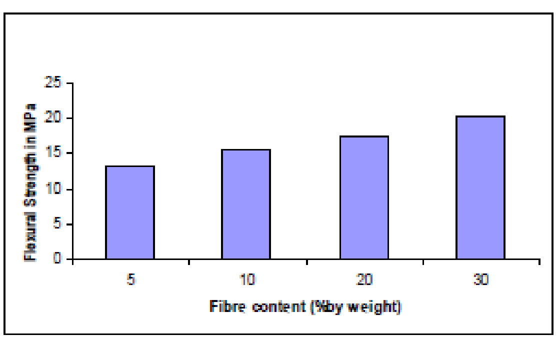
The Mechanical properties of fabricated natural fiber reinforced composites were observed. It is found that polymer banana reinforced natural composites is the best natural composites among the various combination. It can be used for manufacturing of automotive seat shells among the other natural fiber combinations.

P.S.Souza et al[7]In this work the mechanical properties of high density polyethylene/textile fibers residues composites were studied. Effect of pretreatment with sulfuric acid on textile fibers to prepare composites was made to provide an improvement in mechanical properties of these materials. This treatment on fibers was evaluated by X-ray diffraction technique. Composites were produced in a thermo kinetic mixer in the following composition: 5 and 10 wt% fibers. After mixing the samples were injection molding according to ASTM D-638 specification. Specimens were tested in tensile mode and composite fractures surface were analyzed in a scanning electron microscopy. Also was studied moisture absorption. Results showed that HDPE/ textile fibers residue presents good mechanical performance compared with high-density polyethylene. After conducting the experimental work and discussing theresults relieved that addition of modified textile fibers from industrial residue to matrix (HDPE) improved the tensile strength and modulus, well as moisture water.

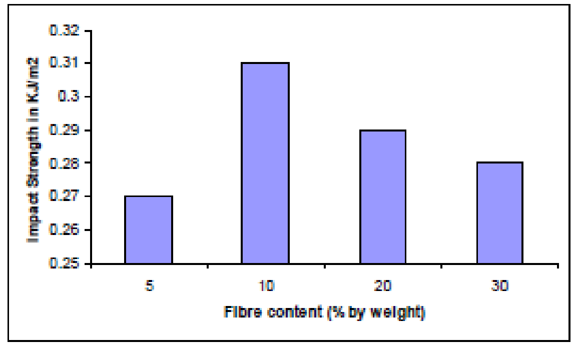
A.Alavudeen et al [8]In this work banana fiber with different proportion was used as reinforcements to polymer based matrices. The effects of fibers content on mechanical properties of banana fiber composite materials were studied. After the Experiment, it was observed that in banana fibers/polymer matrix composites that increasing the amount of fiber content resulted in increasing the tensile and flexural strength. On the other hand, the addition of banana fiber to the matrix was found a scatter on the impact strength.



Graph 1. Effect of fiber content on tensile strength [8]



Graph 2. Effect of fiber content on flexural strength [8]



Graph 3. Effect of fiber content on impact strength [8]

These results suggest that one can obtain the better mechanical performance on the banana fiber polymer composites with correct or optimum wt% and length of banana fibers.

E.F. Cerqueira et al [9] Recently the interest in composite materials reinforced with natural fibers has considerably increased due to the new environmental legislation as well as consumer pressure that forced manufacturing industries to search substitutes for the conventional materials, e.g. glass fibers. This way, the objective of paper was evaluate the effect of chemical modification on mechanical properties of sugarcane bagasse fiber/PP composites. Fibers were pretreated with 10% sulfuric acid solution, followed by delignification with 1% sodium hydroxide solution. These fibers were mixed with the polypropylene in a thermokinetic mixer, and compositions with 5 to 20 wt% of fibers were obtained. The mechanical properties were evaluated by means of tensile, 3-point bending and impact tests. In addition, fracture analysis via SEM (secondary electrons mode) was performed. Results showed improve the tensile, flexural and impact strength of the composites in comparison to the polymer pure.

J.Sahari et al [10]Numerous research groups have explored the production and properties of biocomposites where the polymer matrices are derived from renewable resources such as poly lactide (PLA), thermoplastic starch (TPS), cellulose and polyhydroxyalkanoates (PHAs). This review is carried out to evaluate the development and properties of natural fiber reinforced biodegradable polymer composites. After performing the experiment the result was that they are the materials that have the capability to fully degrade and compatible with the environment, in addition the mechanical properties was observed and found that there was good result in tensile, flexural ,hydrophilic and thermo-mechanical properties, which can give benefit to all mankind and environmental issue.

Hoi-yan Cheung et al[2]Research on biodegradable polymeric composites, can contribute for green andsafe environment to some extent. In the biomedical and bioengineered field, the use of natural fibermixed with biodegradable and bioresorbable polymers can produce joints and bone fixtures to alleviate pain for patients. The mechanical properties in terms of the elastic modulus and ductility of these biocompositesincreased substantially compared to the neat polymers. The mechanical properties of most of plant-based fiber composites increased with increasing the amount of fiber into polymer matrix. However, the ultimate strength decreased as expected. From those experimental results, incorporation of the fibers gave rise to a considerable increase of the storage modulus (stiffness) and to a decrease of the tan delta values. These results demonstrate the reinforcing effect of animal-based fiber on PLA matrix. It also reveals that biocomposite with small amount of animal fiber provided also better thermal properties as compared with pristine polymers.

A.S Singh et al [11] In the present communication, a study on the synthesis and mechanical properties of new series of green composites involving Hibiscus sabdariffafiber as a reinforcing material in urea–form-aldehyde (UF) Amino resin based polymer matrix has been reported. Static mechanical properties of randomly oriented intimately mixed Hibiscus sabdariffafiber reinforced polymer composites such as tensile, compressive and wear properties were investigated as a function of fiber loading. Initially urea–formaldehyde resin prepared was subjected to evaluation of its optimum mechanical properties. Then reinforcing of the resin with Hibiscus sabdariffafiber was accomplished in three different forms: particle size, short fiber and long fiber by employing optimized resin. Present work reveals that mechanical properties such as tensile strength, compressive strength and wear resistance etc of the urea–formaldehyde resin increases to considerable extent when reinforced with the fiber.And concluded that mechanical behaviour particle reinforcement of the UF resin has been found to be more effective as compared to short fiber reinforcement. These results suggest that Hibiscus sabdariffafiber has immense scope in the fabrication of natural fiber reinforced polymer composites having vast number of industrial applications.

L. Averous at al [12] This paper is focused on the analysis of the thermal and mechanical behaviour of processed biocomposites (biodegradable composites). These materials have been created by extrusion and injection moulding. The matrix, a biodegradable and aromatic copolyester (polybutyleneadipate-co-terephthalate), has been fully characterised (NMR, SEC). The lignocellulosic materials used as fillers are a by-product of an industrial fractionation process of wheat straw. Different filler fractions have been selected by successive sieving, and then carefully analysed (granulometry, chemical structure). Cellulose, lignin, and hemicellulose contents have been determined through different techniques. The biocomposites thermal behaviour has been investigated by TGA (thermal degradation) and DSC (transition temperatures, crystallinity). These materials present good mechanical behavior such as tensile strength, modulus due to high filler-matrix compatibility. The impacts of filler content, filler size and the nature of each fraction have been analysed.

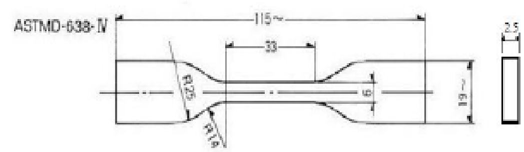
Mr. Vignesh at al [13] In this work an attempt has been made to develop a biocomposite material using untreated dupion silk fiber as reinforcement material and vinylester as matrix material with Potato Starch used as filler material by hand layup technique. The biocomposites were prepared in varying percentage of filler addition (0%, 10%, 20%, and 30%) and different mechanical tests (tensile, flexure and hardness) were conducted on the samples prepared to the ASTM standards.

Table 5.Composition of Biocomposite [9]

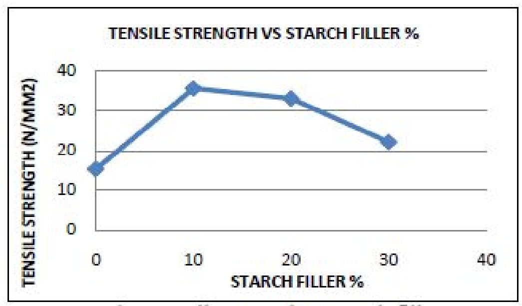
Samples	% of Resin	% of Fiber	% of Filler
A	90	10	0
B	80	10	10
C	70	10	20
D	60	10	30

After performing the experiment we obtain,

Tensile test - Tensile tests on composite specimens were carried out according to ASTM–D 638 standard to determine tensile strength and to observe the behavior of biocomposites under load.



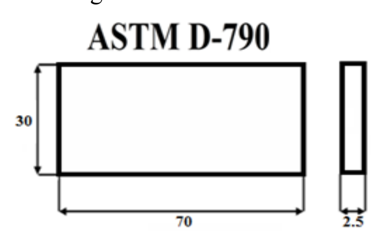
Standard tensile specimen dimension



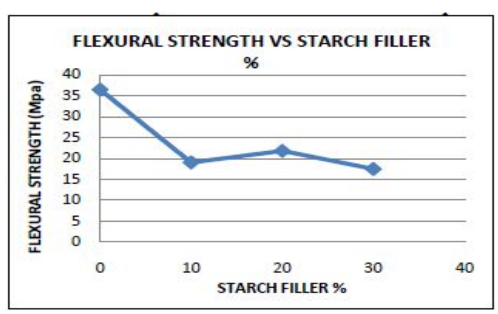
Graph 4.Tensile strength vs Starch filler [9]

For all the Bio-composites tested, it is observed that the Peak Load and tensile strength increases up to 10% filler content then it starts to reduce from that point for higher fillerpercentage. Hence 10% filler content has better tensile properties compared to the 0%, 20%, 30% filler content

Flexural test - Flexural tests on composite specimens were carried out according to ASTM D-790 standard.



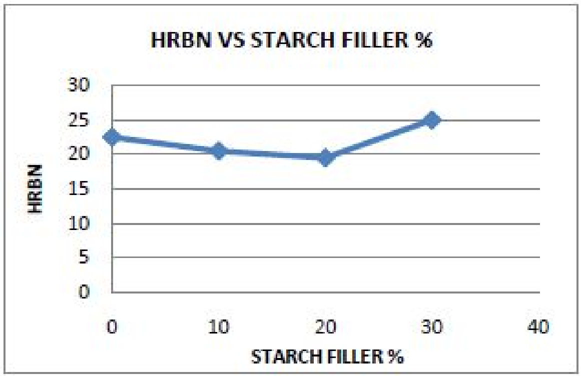
Standard flexural specimen dimensions



Graph 5.Tensile strength vs Starch filler [9]

The flexural strength is highest for 0% filler content, it reduces and remains almost constant for 10%, 20%, and 30%

Rockwell Hardness test - The Rockwell hardness is determined by the depth of the indentation in the test material resulting from application of a given force on a specific indenter.The hardness test results shows that 30% filler content Biocomposites has better Hardness number.



Graph 6.HRBN vs Starch filler [9]

Therefore from the results of the experiments conducted on the specimen it can be concluded that the performance of 10% Starch filler content Biocomposite is satisfactory in all aspects compared to 0%, 20%, and 30% Starch fillercontent Biocomposites

V. APPLICATION

The The application of the natural fiber composites depends on yhe production cost of COTS and their functional properties. The requirements of light weight, low cost and nevertheless the reduction of the CO_2 turn the manufacturers of all the industry to pay more attention of the renewable raw materials. The utilization of the natural fibers offers the potential to replace a large segment of the glass fiber and mineral fillers at a much lower cost. Door panels, Seat backs, Headliners, Package trays, Dashboards and Pultruted tubes are made by natural fibers reinforced thermoset or thermoplastic resin.

CONCLUSION

Natural fiber reinforced biodegradable polymer composites appear to have very bright future forwiderange of applications. These biocompositematerials with various interesting properties may soon be competitivewith the existing fossil plasticmaterials. However, the present lowlevel of production and high cost restrict them for to be applied in industrial application. In addition, its hydrophilic properties makes the real challenge to design the product which can can be good candidate for outdoor applications. Biomposites have been used extensively in applications such as pipes and pressure vessels. Therefore there is need for further studies on the physical and mechanical properties of these materials. Thus, further research and improvement should be conducted so that these fully degraded composites can easily be manipulated and can give benefit to all mankind and environmental issues.

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