Review on Natural Fiber in Various Pretreatment Conditions for Preparing Perfect Fiber

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Article Received: 23 February 2017 *Article Accepted: 06 March 2017* *Article Published: 11 March 2017*

ABSTRACT

In present scenario natural fibers have received much attention because of their light weight, nonabrasive, combustible, nontoxic, low cost and biodegradable properties. Among the various natural fibers, banana fiber was focused for its pretreatment conditions for preparing perfect fiber. In previously many researchers have found various fibers have been pretreated and they obtain its properties and its applications. In this project banana fiber has been taken as natural fiber and it was pretreated and its properties after pretreatment were obtained. The pretreatment was alkali, sodium hydroxide, potassium permanganate treatment, and bleaching was carried out. Then the composite specimen boards were fabricated by various pretreatment banana fiber, polyethylene and matrix. It undergone to mechanical testing, tensile test, hardness test and also SEM analysis was carried out to check their microstructure. The perfect fiber was found by the obtained results from their properties and bonding nature.

Keywords: Natural fiber, Filler materials, Resin, Pretreatment and Reinforcement.

1. Introduction

With increasing numbers of applications and mass volume uses, in particular, recording double-digit growth worldwide, disposal of composites after their intended life is already becoming critical, as well as expensive. Because composites are made using two dissimilar materials, they cannot be easily recycled or reused. Most composites end up in landfills, while some are incinerated after use, although there are some efforts to recycle and/or reuse them. Both these disposal alternatives are expensive and wasteful, and may contribute to pollution. In addition, landfills are decreasing in number, making less space available to discard waste. Many applications, e.g. secondary and tertiary structures and those used in consumer products for casing, packaging, etc., do not require the high mechanical properties that advanced composites possess. Since many of the fibers and resins are made using non-degradable, mostly petroleum based materials, once discarded they do not degrade for several decades under normal environmental conditions. This exacerbates the existing ecological and environmental problems.

The use of biodegradable and environment-friendly plant based ‘lignocellulosic’ fibers has been a natural choice for reinforcing (or filling) polymers (plastics) to make them ‘greener’. The availability of inexpensive plant-based fibers in every part of the world has, in part, fueled their use in the past few years. These fibers offer several other advantages as well. They are nonabrasive to processing equipment, can be incinerated, are CO_2 neutral (when burned), and, because of their hollow and cellular nature, perform well as acoustic and thermal insulators3. The hollow tubular structure also reduces their bulk density, making them lightweight. Plenty of examples can be found of the use of plant-based fibers for reinforcing non-degradable thermoplastic polymers such as polypropylene (PP); high, medium, and low density polyethylenes (HDPE, MDPE, LDPE); nylons; polyvinylchloride (PVC); and polyesters to produce what may be termed ‘greener’ composites. Examples can also be found of plant based fibers that have been used with thermosetting resins such as epoxy and polyurethane.

With concern to the industrial applications, several paths have been undertaken. In short, it can be stated that the most used natural organic filler is wood (either flour or fibers), especially as low cost filler for polyolefins. Wood flour is usually obtained from sawmill waste after a simple sieving treatment; wood fibers are produced from sawmill waste by a wet thermo mechanical process. Already explored industrial applications include window and door frames, furniture, railroad sleepers, automotive panels and upholstery, gardening items, packaging, shelves and in general those applications which do not require very high mechanical resistance but, instead, low purchasing and maintenance costs. Furthermore, it is possible and convenient to use recycled polymers in place of virgin ones, thus assuring improved cost-efficiency and eco-sustainability. Some examples of industrial applications can be easily found on the technical literature and on the Internet; these include, for instance, indoor furniture panels, footboards and platforms, automotive panels and upholstery, noise insulating panels, etc., mainly produced by American, German, Japanese, British and Italian firms.

The mechanical properties of composite materials are known to depend on (i) the type of fiber used, and especially its morphological characteristics (aspect ratio), (ii) the filler content, (iii) the dispersion and orientation of fibers within the polymer matrix, and (iv) the adhesion at the interface between the polymer matrix and fibers, since a good adhesion ensures a good stress transfer from the matrix to the filler. As well described in literature (Bennick, 2002; Papadopoulou and Frazier, 2004; Sarni-Manchado et al., 1999), polyphenol/protein interactions led to expect a good affinity between wheat gluten and lignocellulosic fibers due to the presence of lignin, which is a polyphenolic compound, on the surface of fibers. In this context, Kunanopparat et al. (2008a) studied the effect of introducing increasing content of natural fibers coming from hemp and wood on the mechanical properties of wheat gluten-based composite materials. They found that the fiber content significantly affect the mechanical properties of wheat gluten-based materials (increase in the tensile strength and the Young's modulus and decrease in the elongation) while the origin of fibers had no effect even though wood fibers contained more lignin than hemp fibers. (Biocomposites from wheat proteins and fibers: Structure/mechanical properties relationships, Beatriz Monta no-Leyvaa,b, Gabriela Ghizzi D. da Silva a, Emmanuelle Gastaldia, Patricia Torres-Chávezc, Nathalie Gontarda, Hélène Angellier-Coussya,).

2. PROPERTIES OF NATURAL FIBERS

Table 1. Properties of Natural Fiber

FIBER	DENSITY (g/cm^3)	MOISTURE CONTENT (wt. %)	ELONGATION AT BREAK (%)	FRACTURE STRESS (MPa)	YOUNGS MODULUS (GPa)
COTTON	1.5	-	7.0	287	5.5
JUTE	1.3	12.6	1.5	393	26.5
FLAX	1.5	10.0	2.7	345	27.6
HEMP	-	10.8	1.6	690	-
SISAL	1.5	11.0	2.0	511	9.4
COIR	1.2	8.0	30.0	175	4.0
BAMBOO	0.8	-	-	391	48
SOFT WOOD	1.5	-	-	1000	40
PINEAPPLE	-	11.8	1.6	413	34.5
RAMIE	1.5	8.0	3.6	400	61.4
BANANA	-	-	2.5-3.7	700-800	27-32

3. METHODOLOGY

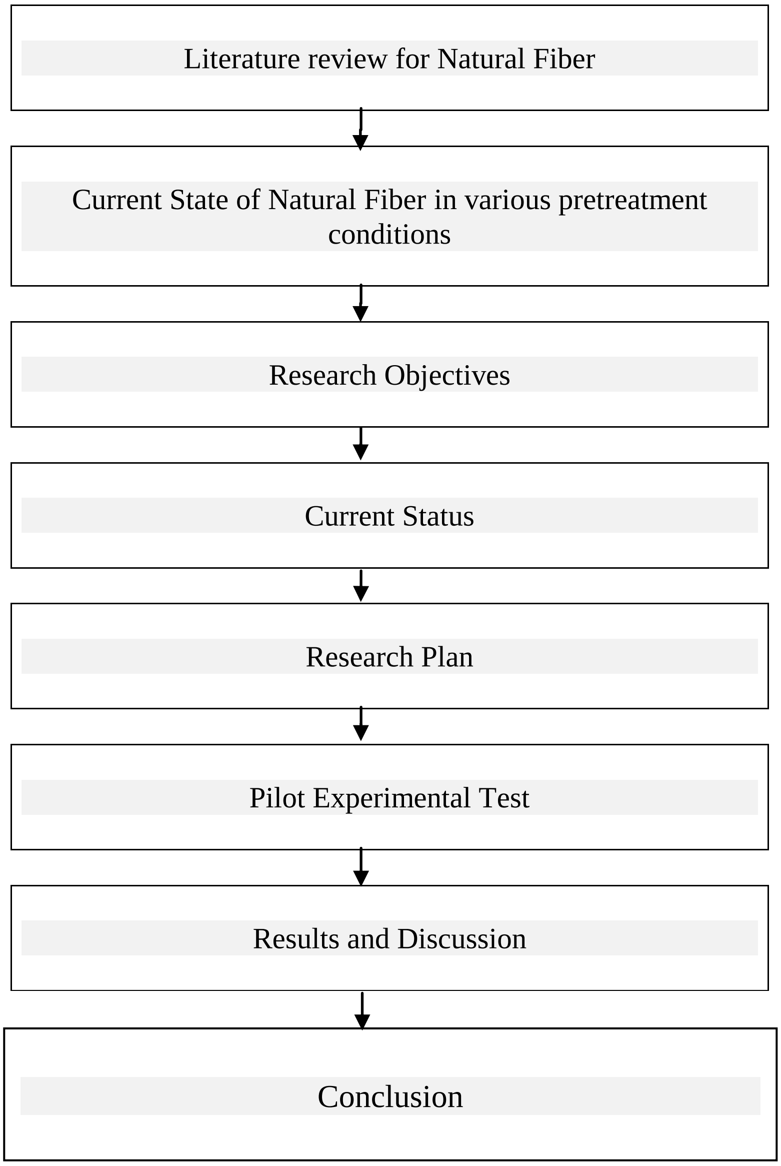

Fig.1. Methodology

4. RESEARCH OBJECTIVES

1. To study, Explore, Identify the current state of research in the field of composites by using Natural fibers reinforced for using industrial applications.

2. To study the Banana fiber and various pretreatment process.

3. To study the selection of material and data collection.

4. To study the existing various mechanical property analysis like wear test, hardness test, tensile test, impact test and SEM analysis.

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5. EXPERIMENTAL WORK

5.1. Preparation of the Natural fiber

5.1.1. Natural Fiber

Natural fibers can be classified according to their origin and grouped into leaf: abaca, cantala, curaua, date palm, henequen, pineapple, sisal, banana; seed: cotton; bast: flax, hemp, jute, ramie; fruit: coir, kapok, oil palm; grass: alfa, bagasse, bamboo and stalk: straw (cereal). The bast and leaf (the hard fibers) types are the most commonly used in composite applications. Commonly used plant fibers are cotton, jute, hemp, flax, ramie, sisal, coir, henequen and kapok. The largest producers of sisal in the world are Tanzania and Brazil. Henequen is produced in Mexico whereas abaca and hemp in Philippines. The largest producers of jute are India, China and Bangladesh. Natural fibers have so many advantages such as abundantly available, low weight, biodegradable, cheaper, renewable, low abrasive nature, interesting specific properties, as these are waste biomass and exhibit good mechanical properties. Natural fibers also have some disadvantages such as moisture absorption, quality variations, low thermal stability and poor compatibility with the hydrophobic polymer matrix.

5.2. Types of Natural Fibers

- Cotton
- Jute
- Flax
- Hemp
- Sisal
- Coir
- Bamboo
- Pineapple
- Ramie
- Banana

5.2.1. Fiber Reinforcement

Fibers are the important class of reinforcements, as they satisfy the desired conditions and transfer strength to the matrix constituent influencing and enhancing their properties as desired. The use of chemical treatment has a strong influence on the fiber matrix bond and revealed excellent interfacial adhesion properties of the fiber and the matrix, which accelerate the industrial use of these fibers in all over the world. And make them suitably applicable for automotive industry, construction, aerospace, packaging, etc.

5.2.2 Banana

Banana is one of the rhizomatous plants and currently grown in 129 countries around the world. It is the fourth most important global food crop. Different parts of banana trees serve different needs, including fruits as food sources, leaves as food wrapping, and stems for fiber and paper pulp. Historically, banana stems had been used as a source of fiber with the earliest evidence around the 13th century. But its popularity was faded after other convenient fibers such as cotton and silk were made available. As fiber industry has been developing to increase production efficiency, new fibers were then developed to effectively respond the consumers' need, including the production of man-made fibers using petroleum to optimize the fiber properties. The chemical use inevitably causes contamination in every environmental medias water, soil and air, which directly affects human wellbeing and environment. In banana plantations, after the fruits are harvested, the trunks or stems will be wasted. Billion tons of stems and leaves are thrown away annually. Such waste provides obtainable sources of fibers, which leads to the reduction of other natural and synthetic fibers' production that requires extra energy, fertilizer, and chemical. The properties of banana fiber are good absorbent, highly breathable, quickly dry with high tensile strength.

This research is to develop banana fiber from the plant that is available locally throughout the country of Thailand but rarely used as fiber source in textile industry. The focus of the study is to optimize the fiber producing processes of in an environmental friendly manner and decrease chemicals and toxic agents incurred. The findings were 25-30% yield for fiber collection and the mechanical process (fresh method) is an appropriate method of fiber extraction. The yarn spinning and knitting were experimented but the results have not been satisfied, yet. Further study should be developed. As banana fiber can provide a wide variety of uses in textile and paper industry, the study the application of this locally and widely grown plant species for the sustainable development would be beneficial.

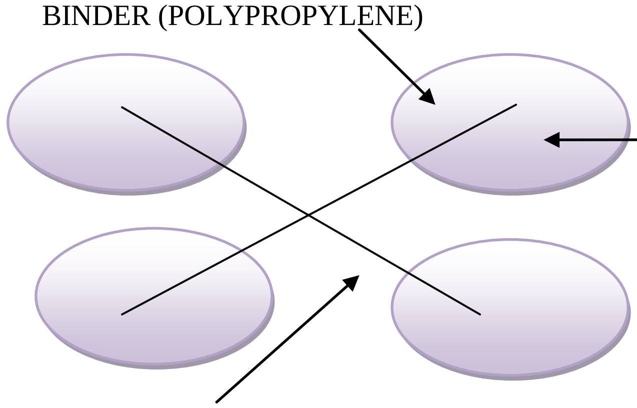

Fig.2. Basic structure of Green composite

Table.2. Banana Fiber Properties

FIBER PROPERTIES	UNITS
Tenacity	29.98 g/denser
Fineness	17.15 denser
Moisture regain	13.00 %
Elongation	6.54
Alco-ben extractives	1.70 %
Total cellulose	81.80 %
Alpha cellulose	61.50 %
Residual gum	41.90 %
Lignin	15.00 %

5.2.3 Fiber

The research and development in utilizing banana fiber have not been generally conducted. Currently, there are only a few developments trying to fully utilize natural fibers, including banana fibers and its parts. In Australia, the researcher has developed paper technology by using banana trunk as raw material and cross-plying technique (papyrus paper technique) to produce banana paper. Banana paper is much stronger than regular paper. They use it for cement bags (25 kilograms weight) and other heavy duty bags [4]. Since the tenacity of banana fiber is very high, therefore some automobile companies use it to reinforce the body of the vehicle. The European Union's legislation forced producers to increase their products' recyclability and biodegradability. Efforts have been made in the environmental conscious to avoid high disposable cost according to the legislation. For example, DaimlerChrysler, a global corporation, maintains the standards of environmental concern in their operation in other countries where these requirements are not yet exist. In 1991, POEMA tec Alliance, Daimler-Benz, Mercedes-Benz do Brazil in Sao Paulo carried substitute synthetic inputs with natural fibers for interior car parts.

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Fig.3. Banana Fiber

Since natural fibers such as coconut, banana, is 100% biodegradable, there is no significant energy costs associated with processing waste and recycling because the waste fibers are wither fed back into the processing cycle. Coconut fiber is employed for headrest and car seat. Consequently, using natural fiber products provides value in projecting a positive public image. Scholars have explored banana fibers in composite material. Cellulosic fibers, such as banana fiber, are used to decrease cost as filler in plastic industry (composite material). The composite with high tensile strength can be obtained using banana combined with glass fiber in the fabric form. The strength impact of the composites increases with the number of layers and fiber volume fraction.

5.2.4. Applications of Banana Fiber

In the recent past, banana fiber had a very limited application and was primarily used for making items like ropes, mats, and some other composite materials. With the increasing environmental awareness and growing importance of eco-friendly fabrics, banana fiber has also been recognized for all its good qualities and now its application is increasing in other fields too such as apparel garments and home furnishings. However, in Japan, it is being used for making traditional dresses like kimono, and kamishimo since the Edo period (1600-1868). Due to its being lightweight and comfortable to wear, it is still preferred by people there as summer wear. Banana fiber is also used to make fine cushion covers, Necties, bags, table cloths, curtains etc. Rugs made from banana silk yarn fibers are also very popular world over.

5.2.5. Matrix

The role of matrix in a composite is

- To transfer the load to fiber.
- Continuous phase support the fibers in the composite.
- Protect the fiber from environment metal damage and mechanical damage and mechanical abrasion, etc.
- Reduce the crack propagation by virtue of its ductility.

5.2.6. Filler Materials

The most widely known and used natural-organic fillers are wood flour and fibers. Wood flour can be easily and cheaply obtained from sawmill wastes and it is usually used after proper sieving. Wood fibers are produced by thermo-mechanical processes on wood waste. Besides wood derivatives, other natural-organic fillers have begun to find application as well. Among these, some examples are cellulose, cotton, flax, sisal, kenaf, rice husks, jute, hemp, starch. Further ‘‘environment-friendliness’’ can be achieved upon using post-consumer recycled plastics in place of virgin polymer matrices.

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Wood flour and fibers are quite interesting because of the low cost, dimensional stability, elastic modulus, while tensile properties do not improve; the main shortcomings are the poor adhesion between the filler particles and the polymer matrix, low impact strength, thermal decomposition at temperatures over 200^0C. Flax, sisal, hemp and kenaf are relatively similar and are basically long fibers extracted from the bast of the plants; they can be used as fillers by proper cutting into long or short fibers.

Starch is a polysaccharide present in many plants acting as an energy reservoir. It is made of glucose monomers linked by a-(1-4) bonds. In general, the addition of granular starch to a polymer leads to a reduction of the elongation at break (and often of the tensile stress as well), as high as the starch content increases, while the elastic modulus is enhanced. A limitation of this filler type is the tendency to absorb water because of its very high surface area and its hygroscopic nature. Other less used natural-organic fillers can include rice husk ash, nutshells, oil palm empty fruit bunch fibers, corn plants extracted fibers, etc.

5.2.7. Reason for Choosing Rice Husks

In this project rice husks has been choose as a filler material. Because it can be obtained very abundantly in Tamilnadu especially in Thanjavur. The rice husks is a waste material also it is a Biodegradable material, so it can be decomposed easily. Rice hulls (or rice husks) are the hard protecting coverings of grains of rice. In addition to protecting rice during the growing season, rice hulls can be put to use as building material, fertilizer, insulation material, or fuel. Rice hulls are the coating for the seeds, or grains, of the rice plant. To protect the seed during the growing season, the hull forms from hard materials, including opaline silica and lignin. The hull is mostly indigestible to humans. One practice, started in the seventeenth century, to separate the rice from hulls, it to put the whole rice into a pan and throw it into the air while the wind blows. The hulls are blown away while the rice fell back into the pan. This happens because the hull isn't nearly as dense as the rice.

Fig.4. Rice Husks

5.2.8. Polypropylene

Literature reports several studies on polypropylene in combination with fillers derived from wood, flax, sisal, hemp, kenaf, and starch. The spur towards alternate cellulose sources finds a justification in the fact that these are more easily renewable than the wood itself. Adhesion promoters are used as well. Some examples reported in the literature regard silane-based compounds, maleic anhydride grafted polypropylene (MAg- PP), styrene–ethylene–butadiene–styrene rubber grafted with maleic anhydride (MAgSEBS), ethylene propylene diene copolymer grafted with maleic anhydride (MAgEPDM), which allowed obtaining a significant improvement of mechanical and morphological properties. Interesting results have been also found regarding the effect of wood fibers on crystallization and morphology of polypropylene-based composites. It has been confirmed that wood fibers do not influence significantly the crystal growth kinetics, while can enhance nucleation rates. The addition of MAgPP further increased nucleation phenomena, but it is not clear whether the observed improvement of mechanical properties should be attributed mainly to an enhancement of wood–polymer adhesion, to a better wood dispersion, or both. It is also proposed that the polymer structure, in particular the presence of amorphous regions, may have an important role on the worsening of some mechanical properties.

5.3 EXPERIMENTAL PROCEDURE

5.3.1.Pretreatment of fiber

Fiber processing technology like microbial deterioration and system explosion plays an important role in improving the quality of fibers. The condition reached thereby are decisive for the energy necessary for delignification and fibrillation and thus also for the attainable fiber masses. To obtain a value gain, the more important is to retain the super molecular structure of the fibers. The traditional microbial deterioration process is one of the most important prerequisite. In new steam explosion method, steam and additives under pressure and with increased temperature, penetrate the space between fibers of the bundle, because of which the middle lamella and the fibers adherent substances are element aroused softly and are made water soluble which can be removed by subsequent washing and rinsing. Market prices for natural fibers are crucial factor though the natural fibers are of better strength but they are about 30% more expensive than glass fibers.

5.3.2. Various Pretreatments for Natural Fibers

Alkali treatment (also called mercerization): it is usually performed on short fibers, by heating at approx. 80 _C in 10% NaOH aqueous solution for about 3–4 h, washing and drying in ventilated oven. It allows disrupting fiber clusters and obtaining smaller and better quality fibers. It should also improve fiber wetting.

Acetylation*:* the fibers are usually immersed in glacial acetic acid for 1 h, then immersed in a mixture of acetic anhydride and few drops of concentrated sulphuric acid for a few min, then filtrated, washed and dried in ventilated oven. This is an esterification method which should stabilize the cell walls, especially in terms of humidity absorption and consequent dimensional variation.

Treatment with stearic acid*:* the acid is added to an ethyl alcohol solution, up to 10% of the total weight of the fibers to be treated the obtained solution is thus added drop wise on the fibers, which are then dried in oven. It is an esterification method as well.

Benzylation*:* the fibers are immersed in 10% NaOH and then stirred with benzoyl chloride for 1 h, filtrated, washed and dried, then immersed in ethanol for 1 h, rinsed and dried in oven. This method allows decreasing the hydrophilicity of the fibers.

TDI treatment: the fibers are immersed in chloroform with few drops of a catalyst (based on dibutyltin dilaurate) and stirred for 2 h after adding toluene-2,4-diisocyanate. Finally, fibers are rinsed in acetone and dried in oven.

Peroxide treatment*:* the fibers are immersed in a solution of dicumyl (or benzoyl) peroxide in acetone for about half an hour, then decanted and dried. Recent studies have highlighted significant improvements in the mechanical properties.

Anhydride treatment*:* it is usually carried out by utilizing maleic anhydride or maleated polypropylene (or polyethylene) in a toluene or xylene solution, where the fibers are immersed for impregnation and reaction with the hydroxyl groups on the fiber surface. Literature reports significant reduction of water absorption.

Permanganate treatment*:* the fibers are immersed in a solution of $KMnO_4$ in acetone (typical concentrations may range between 0.005 and 0.205%) for 1 min, then decanted and dried. Investigations have pointed out a decreased hydrophilic nature of the fibers upon performing this treatment.

Silane treatment: the fibers are immersed in a 3:2 alcohol water solution, containing a silane-based adhesion promoter for 2 h at pH _ 4, rinsed in water and oven dried. Silanes should react with the hydroxyl groups of the fibers and improve their surface quality.

5.3.3. Pretreatment Used For Banana Fiber

- Permanganate treatment
- Peroxide treatment
- Alkali treatment
- Acetylation
- Washing with water and drying

5.3.4. Tensile Testing Machine

Tensile testing is a fundamental material science test in which a sample is subjected to uniaxial tension until failure. The results from the test are used to selection of material for quality control, and to predict a material will react under the types of forces.

Fig.5. Tensile Testing Machine

Properties are directly measured from tensile test are ultimate tensile strength, maximum elongation and reduction in area. These measurements of following properties can also be determine are young's modulus, poison's ratio, yield strength, and strain-hardening characteristics. The most common testing machine is used in tensile testing is the universal testing machine.

5.3.5. Hardness Test

The hardness is metal resistance to plastic deformation, usually by indentation. The term refers to stiffness or to resistance to abrasion, or cutting. It is the property of a metal, which gives ability to resist being permanently, deformed when a load is applied. The hardness of the metal is the greater resistance to deformation.

Fig.6. Hardness Test

The property of matter described as the resistance of a substance to being scratched by substance is hardness. The metallurgy is defined as the indentation hardness as the resistance of a material to indentation. This is one type of hardness test, in which a rounded indenter is pressed into a surface under a substantial static load.

5.3.6. Brinell Hardness Test

Brinell hardness test are frequently doing on large parts. The varying test force and ball size, all metals has been tested by using a brinell hardness tester. The hardness values are considered as test force independent as long as the ball size force relationship is the same.

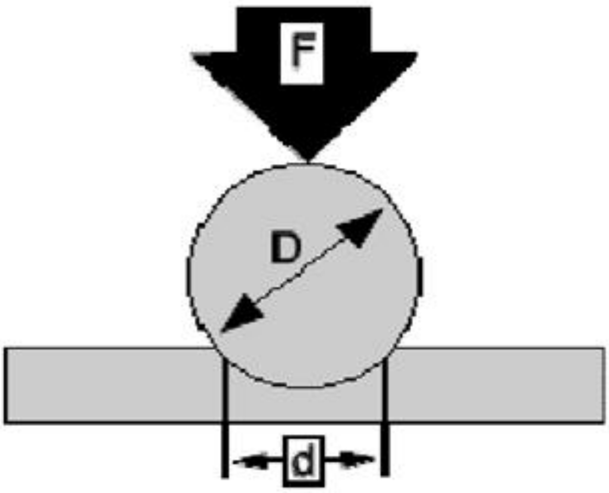

Fig.7. Brinell Test

Brinell hardness testing has done on iron and steel castings by using a 3000 kg test force and 10 mm diameter carbide ball. Aluminum is frequently tested using a 500 kg test force and 10 or 5 mm carbide ball.

5.3.7. Impact Test

The impact test is a dynamic test has been conducted on a selected specimen which is usually notched. The specimen is broken by a single blow in a specially designed machine. It is to measure energy absorption capacity and toughness of the materials. This machine is shown in Fig.11.

Fig.8. Impact Test

5.3.7.1. Charpy Impact Test

The charpy impact test is to determine the amount of energy absorbed by a material during fracture.

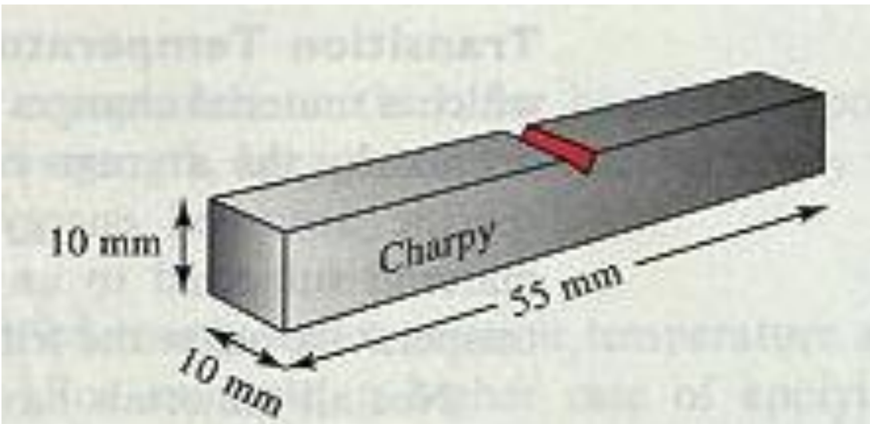

Fig.9. Test Specimen

5.3.7.2. Izod Impact Test

The Izod impact test is an ASTM standard method, which determining the impact resistance of materials. A notched sample is used to determine impact energy and sensitivity of notch.

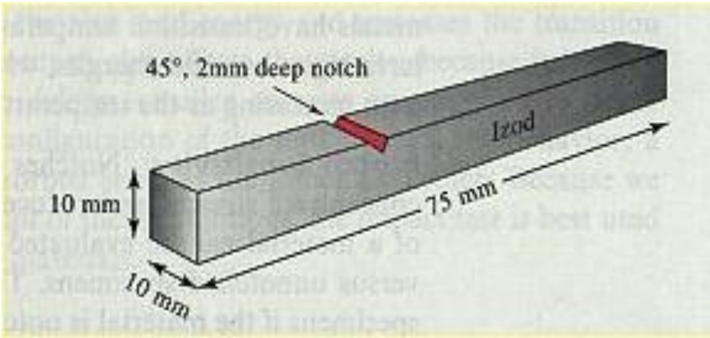

Fig.10. Test Specimen

6. RESULTS AND DISCUSSIONS

Thus the Natural fiber reinforced composites material has been studied successfully and also to study explore, identify the current state of research in the field of banana fiber by using various pretreatment process .The existing various mechanical property analysis like wear test, hardness test, tensile test has been studied and different strengthening mechanism, optimized technique have selected, which is to increase yield strength, impact strength, hardness and reduce the cost and weight of the materials. In future scope the research has been divided into two main categories i.e. (i) fiber with pretreatment and suitable mixing ratio (ii) fiber without pretreatment and suitable mixing ratio.

7. CONCLUSIONS

The banana fiber and its properties, applications were studied. The availability of banana fiber and various pretreatment will be carried out according to the perfect fiber obtained by various pretreatment processes. Before that the fiber, filler material and resin will be choose. The mixing ratio will be chosen and particle board will be prepared. Then the mechanical testing will be carried out and results will be obtained. The project has been divided into two main categories i.e. (i) fiber with pretreatment and suitable mixing ratio (ii) fiber without pretreatment and suitable mixing ratio. According to the better results obtained in the testing the results will be discussed and suitable graphs will be plotted for comparison of results.

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