An Overview of a Natural Cellulosic Fiber from Agave Americana (Sisal) for Eco-Friendly Polymer Composites

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Abstract - In this contemporary world, development in technologies results in environmental and ecological issues due to the increase in the production of synthetic fibers, plastic related various products when compared to Natural fibers reinforced composites. Several researchers are undergoing research involved in the study of NFRC (Natural Fiber Reinforced Polymer). It enhances the properties of plastic. Natural fibers show more economical implementation. Many researchers have researched the Natural fiber from various parts and different plant that has been used in day-to-day life. It plays effective role in industrial sectors and also environmentally safe in nature when compared to other fibers due to their major applications. The aim of this review article is to discuss about various process involved in the extraction of the fiber extraction and fiber's chemical and mechanical characteristics are analyzed by carrying out treatment process such as ALKALINE TREATMENT and by conducting the required tests such as SEM, FTIR, XRD etc. which results in identifying the nature of the natural fiber.

Keywords - Natural Fiber Reinforced Polymer Matrix Composites, Alkaline Treatment, SEM Analysis, Laminated Composites.

I. INTRODUCTION

In the present circumstances Natural Fiber plays a significant role. Natural Fibers are decomposable materials. Natural fibers are inexpensive, sufficiently available and environmentally safe in nature. Natural fibers are often chosen according to their regular basis in their characteristics such as it is cost-efficient, eco-friendly, availability is abundant and has excellent physical properties and it has relatively low density. Scientists have started working on Natural Fiber material due to their chemical and physical characteristics of Natural Fiber. Depending on the climatic conditions, existence according to the place and the age of the Natural fiber defines its chemical and mechanical properties. Furthermore, to other fibers, Natural fibers are strong enough and exhibits very hard property. Natural fiber often possesses higher strength, so it can be applied in major applications such as twines, yawns, carpets, ropes and also in handmade materials due to its higher cellulose content. In recent technology development Natural fibers plays a significant role in Aeronautics Industries. Basically, Natural Fibers are classified into three major aspects they are: Bast fibers, Leaf fibers, Stem fibers. In which Agave fiber comes under leaf fibers.

From the above chart we can clearly the use of the various fibers that are used in the automobile industry. Agave fibers are also known as Sisal Fibers. When compared to other plants Sisal Fibers (plants) has a capability to grow in hot climate condition areas and Arid region/areas [25]. Most importantly Sisal fibers has the potential to grow in all kinds of soils when compared to clay and also the process of cultivation is effortless. Sisal fiber involves different orientation (0º, 45 º, 90º, etc.,). Sisal is a type of hard fiber that is regarded as being tough and coarse. Sisal fibers factors were determined by the qualities of their individual components, lamellae matrix and fibrillar structure. The sisal fiber is managed to built-up with 100 fiber cells when considered in cross-section plane.

Sisal fibers were widely used in composites, due to their phenomenal physical characteristics. Most commonly used machine which is known as HOUNSFIELD TENSOMETER [1] is widely used in testing of sisal fiber tensile strength. The chemical and physical properties widely depend on their strain rate, experimental temperature, fiber diameter and mainly depends on length of the gauge. Sisal fiber has potential application in Automobile sectors. On depending on the area and climatic conditions the cross section of agave fiber may not be similar; it has been varying from circular or elliptical throughout its length. Be it, in polymetric matrices sisal fiber plays an important role as reinforcement. Sisal fiber has a major application in plastic industries as it has low density and good welding specific properties as a

reinforcement in polymers. The cultivation of sisal fiber involves low physical support and can be cultivated in landfills. Compared to other materials, sisal fibers may be purchased commercially year-round for a very low price. Sisal fiber are mainly composed of hemicellulose and lignin. Sisal fibers are very much capable of absorbing water content [2].

Basically, composite based natural fibers are biodegradable and that can be used instead of synthetic fibers. Based on the treatment and selection of natural fiber the properties of the composite material changes. Test like FTIR, TGA, XRD, SEM analysis and treatment like alkaline treatment are done to find the mechanical and chemical properties of sisal fiber. By treating the sisal fiber with NaOH (Alkaline Treatment), in various properties like 2%,4%, 6%, 8%, 10%, etc., the gummy substances, hemicellulose were removed which results in good bonding. As mentioned above, and by carrying out tests like FTIR, XRD, TGA, SEM analysis were used to find the crystalline structure, microscopic images, thermal properties of fiber. Therefore, in this journal, our main aspect is to select the natural fiber and carrying out the chemical treatments and test like FTIR, TGA, XRD, SEM are taken and the results were discussed. **Fig 1** shows the utilization of natural fibers in automobile industries.

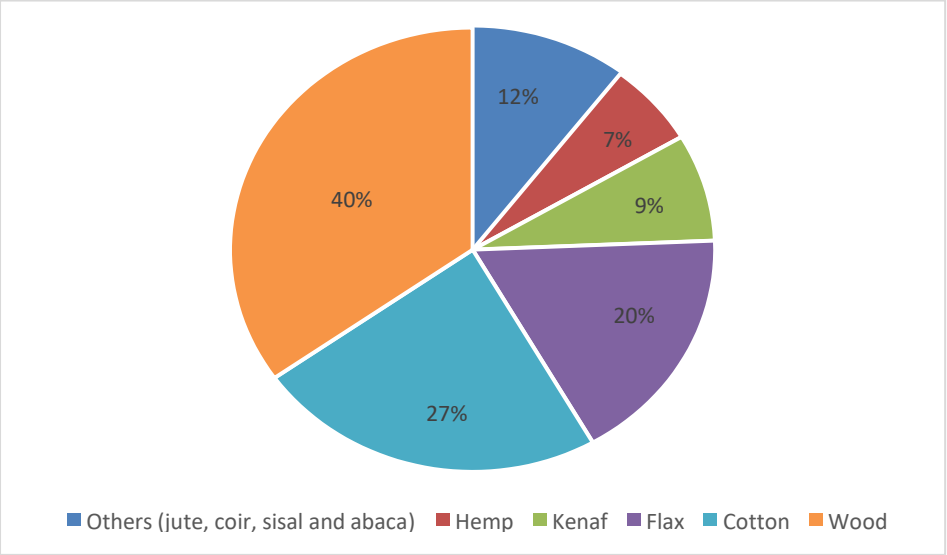

Fig 1. Utilization of Natural Fibers in Automobile Industries [40].

II. MATERIALS AND METHODS

Composite

Composite materials are formed by fusing more than one material with determining factors without dissolving them (Composite = reinforcement + matrix). The major applications of composites are structural properties, electrical, thermal, environmental and tri- biological applications. Composites which are combined of two phases namely reinforcement(fiber) or particle phase which is strong enough and stiffer in nature when compared to continuous matrix phase. It has an adhesive structure formed by physically combining two or more adaptable materials that differ in composition and properties. When composite materials are viewed in a microscopic scale and have same physical properties, they are said to be homogeneous materials, it is said to be heterogeneous when solid phases of a material more than two are closely in contact with one another under nanoscopic level. Most importantly, the characteristics of the composite generally depend on their chemical and physical property of fiber, treatment involved, their type and also includes the structure of the fiber [10].

Reinforcement fibers are natural fibers or man – made synthetic fibers. In our project the sisal fiber is selected as the reinforcement. Matrix holds the reinforcement together, transfer the load among the fibers, it also gives the composite material its overall shape and it is helpful in determining the quality and condition of its surface. The matrix acts to the toughness of the composite as it is more ductile than the fiber. It plays a vital role in protecting the natural fibers from environmental and surrounding damages and during the three stages of composite processing which may include, before process, after process and during the process. Moreover, it serves as a load transmission medium in-between the fiber, in less ideal circumstances with complex loads. The matrix might be required to support loads that are transverse to the fiber axis.

Extraction Of Materials

The extraction process mainly depends on extracting the fiber and gradually eliminating the contaminated materials which includes hemicellulose, pectin, lignin which is present in the fiber and the process is known as retting. Retting process may vary from 14 to 25 days. By further undergoing this retting process, finally in result only the fiber content will be left behind which may result in the moisture break down of the plants muscle content and the bacteria content.

There involve four categories of retting treatment which includes biological, mechanical, chemical and physical fiber separation process. Mechanical and water retting process are used to extract the fibers from the bark. Retting process is of two types they are:1. Process of Dew retting 2. Process of Water retting. **Fig 2** shows the retting process.

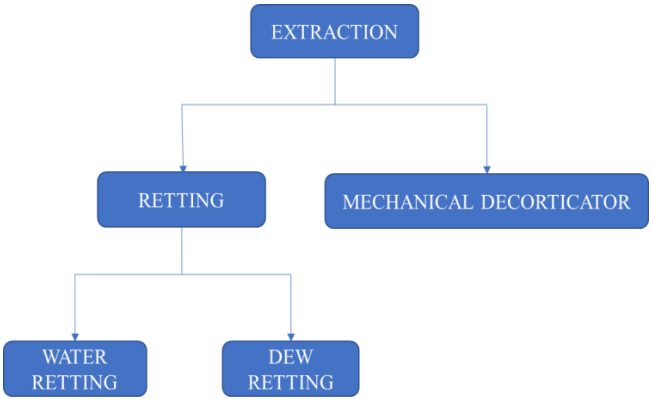

Fig 2. Retting Process.

Dew Retting Process

During dew retting process, stem of the plant is made to scatter for about 2- 3 weeks [40]. Due to the source from the sunlight and moisture content in air, the dew slowly starts to decay and finally by undergoing this process fiber is obtained. This process also takes time according to the climatic conditions and the surrounding area. Most importantly, while going through this process, the daytime temperature should be warm, and night time dew conditions should be high. It is observed that when compared to Water retting process, dew retting process has a dull quality [3].

Water Retting Process

During Water Retting process, agitation aids in the decomposition of the plant'smuscle during this retting process. Here, the plant's stem or leaf is submerged in water for a predetermined amount of time, and the plant tissues breaks down while preserving the fiber content in fermentation process [39]. To prevent fiber damage, which could lead to weak mechanical strength, during this process, time period should be observed. The amount of quality fiber produced, should be maintained for the optimum amount of time [3]. **Fig 3** shows the water retting process.

Fig 3. Water Retting Process.

The fiber extraction process was done through water retting treatment, this process takes a time period of 25 to 30 days of time. During the water retting process, the fiber is immersed in the water as shown in the above fiber and the fermentation process takes place. In the process of fermentation, the tissues of the plant break down. While, performing this type of retting process the fiber should be watched carefully, improper carrying of the treatment process results in the damage of the fiber which results in the poor mechanical strength.

Fiber Type

Sisal fiber has a unique botanical name called “AGAVE AMERICANA”. It comes under the category of species of agave. It is well known for its untoothed arching and twisting leaves. It is able to yield around 100-200cm tall in diameter. On mature plants, they may be capable of extending to a length of 90-180cm and 70-10cm wide close to the base. After following a period of expansion, a flowering stem is more capable and has the potential to reach heights up to 3-5 meters tall is produced. For domestic purpose, its major application in making variety of products such as soap and in

making several brushes, where the plant is harvested from the wild [33-37]. **Fig 4** shows the agave americana.

Fig 4. Agave Americana.

III. TREATMENT AND TESTING:

Chemical Treatment

Basically, natural reinforcement (fibers) is sensitive to water and humidity, the main reason behind isdue to the remaining unwanted materials such as lignin, pectin and hemicellulose which is considered as non-cellulosic materials after the process of extraction of fiber [30-32]. Due to the presence of these cellulose content, it results in creating a large impact on the interfacial adhesion in-between the matrix and fiber because of the hydrophobic content. Interactivity in-between the matrix and the reinforcement were improved during the process of chemical treatment [6, 7, 9]. It is an essential process that reduces the hydrophilic characteristics of the fiber and increasing the bond between the reinforcement and the fiber. There are several treatments such as acetic acid treatment, silane treatment, alkaline treatment, etc., that are particularly used for natural fibers [3].

Among the various chemical treatment process like saline treatment, benzoylation treatment, acetylation treatment, alkaline treatment with the percentage of 1%, 2%, 3%, 4%, 5%, 6%, 7%, 8%, 10% of NaOH treated fibers shows various improved properties by removal of the lignin, hemicellulose and pectin content in the fibers and improves the better bonding strength with the matrix [20-22].

Alkaline Treatment

It is one of the most extensively utilized treatment due to its uncomplicated and efficient processing method. In addition to other chemical treatments the efficiency is observed to be high while undergoing this process with the support of the following chemical solution (it can also be considered as pellet) like NaOH, KOH, Li OH, [5] alkaline treatment process which emphasize on eliminating the hydroxyl group. By undergoing this process which will be helpful in reducing the unwanted non-cellulosic components like a hemicellulose, gummy substances and lignin are eliminated, which helpsin further increase in roughness of the fiber surface which may result in improving the bond in-between reinforcement and matrix. The fiber is then basically treated with various proportion of alkaline like 2%, 4%, 6%, 8%, 10%, etc., which depends on the research and the fiber soaking process [4,23,24,38,11]. Table 1 shows the alkaline treatment and effects of sisal fiber.

Table 1. Alkaline Treatment and Effects of Sisal Fiber

S.no.	Fiber	Chemical Treatment	Effect	Ref.
1.	Sisal	Alkaline Treatment (5% & 10% - 24hr)	Increased the density. Non-cellulosic materials Were removed. Improved better interfacial surface for matrix bonding.	[4]
2.	Sisal	Alkaline Treatment (6% - 30 min)	Improved tensile, flexural, impact strength.	[23]
3.	Sisal	Alkaline Treatment (2% - 12hr)	More removal of lignin content	[24]
4.	Sisal	Alkaline Treatment (5% - 24hr)	Weight loss occurred Non – cellulosic materials were removed.	[38]

5.	Sisal	Alkaline Treatment (1%, 5%, 10% - 1hr)	Removed hemicellulose, lignin at 5%and 10%. Improved tensile strength and stiffness.	[11]

From the **Fig 5**, the Agave fiber is treated with the NaOH at 2%, 4%, 6%, 8% about 1hr. Then the fiber is washed in order to neglect the gummy substances and non-cellulosic contents. After the cleaning porcess the fiber is dried in a oven in order to reduce the moisture content.

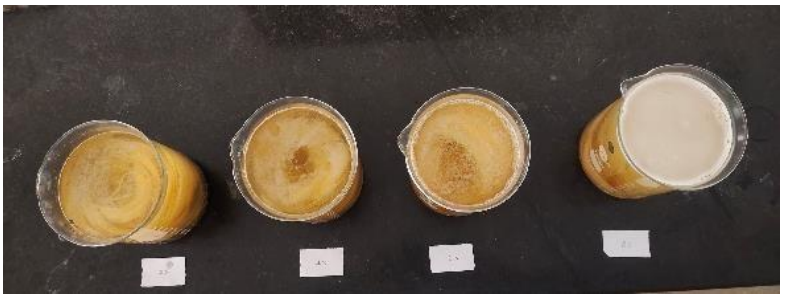

Fig 5. Alkaline Treatment.

SEM Analysis

SEM stands for Scanning Electron Microscope. This process is carried out by using an electron beam to scan the surface of a sample, this specific form of electron microscopic produce a magnified image of the sample. The electrons are accelerated with some amount of kinetic energy and these electrons are decelerated in the solid sample. These signals also have the secondary electrons. These electrons were used for imaging samples. It is designed for studying the surface of the solid objects and also the chemical composition, morphological characteristics, crystalline structure of the sample [12-15].

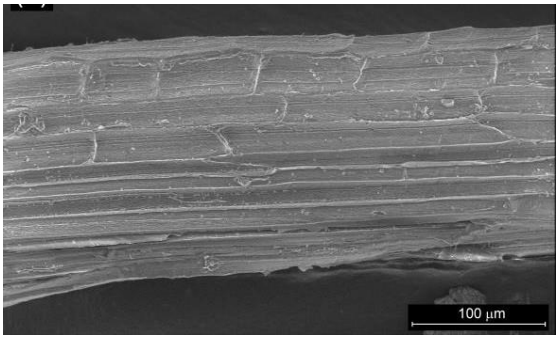

Fig 6. Untreated Fiber [8].

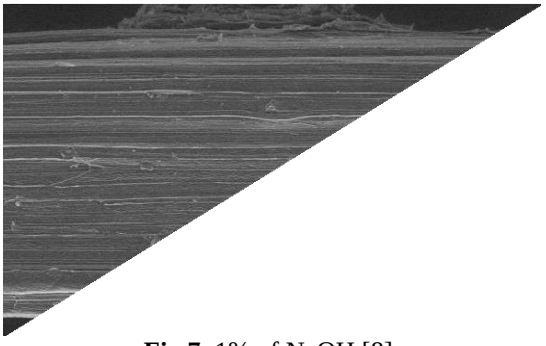

Fig 7. 1% of NaOH [8].

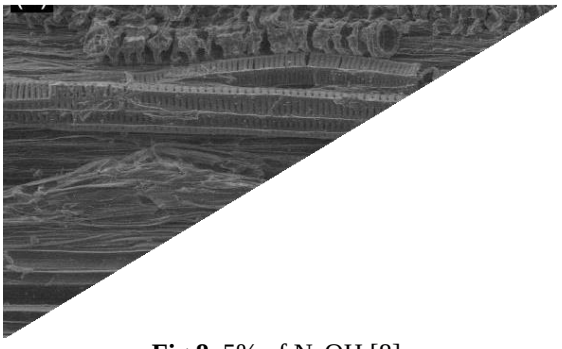

Fig 8. 5% of NaOH [8].

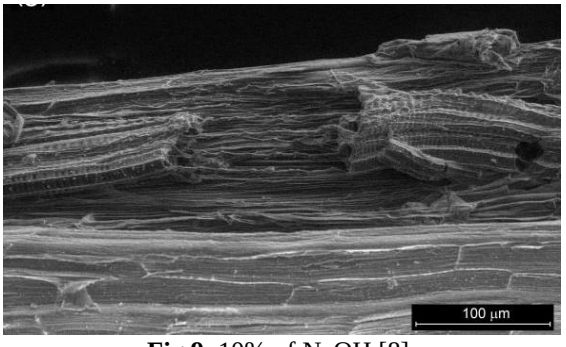

Fig 9. 10% of NaOH [8].

From the images of the SEM analysis, the **Fig 6** is untreated sisal fiber form the **Fig 7** (treated with 1% of NaOH for 1 hr) has less impact of NaOH and there is some removal of surface and it results in smooth surface compared to Figure 6, **Fig 8** (treated with 5% of NaOH for 1hr) shows that the protective barriers of non-cellulosic materials were destroyed and results in rough surface. It also helps in good bonding in-between matrix and reinforcement. **Fig 9** (treated with 10% of NaOH for 1hr) shows high degree of alkalization resulting in the damage of fiber. From the above figures we can

conclude that 5% of NaOH treatment results in the good output to form a composite material [16-19].

Length Ratio

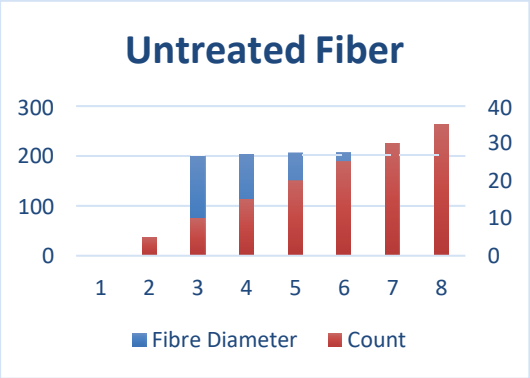

Fig 10. Untreated Fiber [8].

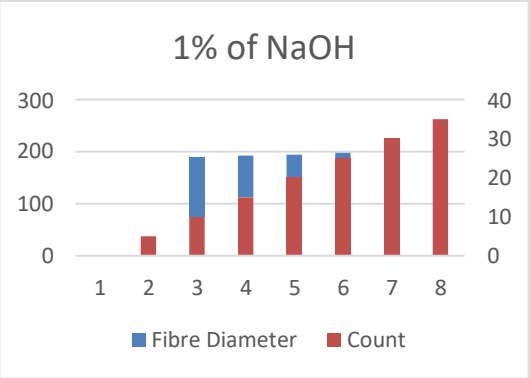

Fig 11. 1% of NaOH [8].

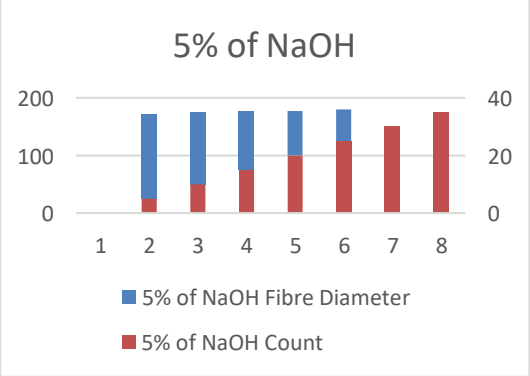

Fig12. 5% of NaOH [8].

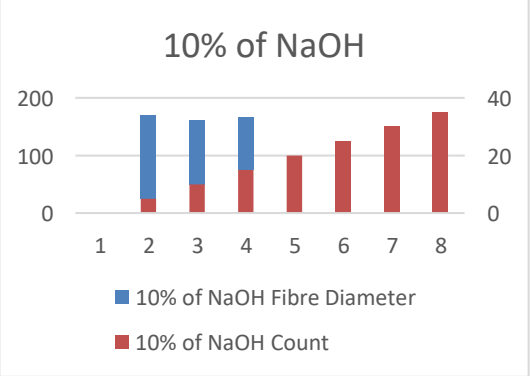

Fig 13. 10% of NaOH [8].

From the above graphs for the various percentages of the fiber we can see that the fiber count for the respective amount of the NaOH with different proportions. **Fig 10** shows untreated fiber, **Fig 11** shows 1% of NaOH, **Fig 12** shows 5% of NaOH and **Fig 13** shows 10% of NaOH by graph.

FTIR Analysis

The principle which is involved in FTIR analysis (FOURIER TRANSFORM INFRARED SPECTROSCOPY) [26], a certain amount of radiation is absorbed by passing on infrared radiation through the sample, the radiation is observed when it passes through the sample. Because varied molecules with varied structure produce different spectra. The spectra which were produced can be used to determine the difference between different molecules. FTIR is the preferred technique for infrared spectroscopy for a variety of purpose. There are major reasons involved, Firstly, it does not damage the sample. Secondly, while comparing to other techniques it is observed that it is considerably faster. The Third reason is that it is more preceptive and accurate [25]. It plays a important role in identifying the compounds such as rubber, paints, resins, compounded plastics and adhesives.

TGA Analysis

TGA represents Thermogravimetric Analyzer this investigation is acted upon to find examples of thermal stability of the sample (Agave Americana). It is the technique usedto study the physical and chemical occurrences in the sample by exposing the sample in temperature variation over a time period. It is mainly known for the study of heat stability of the polymers [36].

XRD Analysis

XRD represents the X-Ray Diffraction. This inspection is carried out to know about the crystalline structure, crystalline size and strain. It is one the most effective analyzing method and requires only minimal sample preparation. In this method the X-Rays are passed on the sample placed in the chamber then by calculating the intensities and the scattering angles of X- rays, calculation is made [27-29]. By this it is possible to determine the crystalline phases, orientation and structural properties like strain, grain size, etc.,

IV. RESULT AND DISCUSSION

By this review, the simplest ways for the extraction of the natural fiber, chemical treatments that are involved in this process, the analysis like SEM that is used to identify the about the structure of the fiber with the help of micro image. By the extraction process the water retting process is employed in it. By this process the fiber is extracted and then dried. After then, the chemical process is carried out with the help of NaOH. The NaOH treatment is employed to remove the non-cellulosic materials like hemicellulose, lignin, pectin was removed based on various ratio of the NaOH that is used. Mostly ratios like 2%, 4%, 6%, 8%, 10% were used with the various proportions of time. With the time difference and the percentage of the NaOH the results will be unique. This treatment gives the good structure for the fiber and gives better bonding with the matrix. Then the SEM (Scanning Electron Microscope) is used to see the structure of the fiber after the chemical treatment by the microscopic image. And there are some other analyses like TGA, XRD, FTIR were used to identify their chemical and physical properties and their principle were discussed in this review. Thus, it has been understood that, the chemical treatment for the natural fibers improves the physical characteristics and the with the help of SEM analysis the structure of the fiber is identified.

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