Experimental Investigation on Mechanical Properties of Agave Americana Leaf Fiber Reinforced Composites with TiO_2

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Abstract— In the growing environmental problems, the waste disposal and the dwindling of limited amounts of exhaustible resources have stimulated the use of green materials compatible with the environment to reduce environmental impacts. Therefore, there is a need to use natural resources in the design of products we have extracted Americana leaf fiber mixed with epoxy as hardner and nano particle as Titanium dioxide. Natural fibres found to be a good alternative since they are abundantly available and there are a number of possibilities to use all the components of fibre-yielding crop; one such fibre-yielding plant is Agave Americana. The fibres yielded by the leaves. The plant's "zero-waste" use would allow its production and processing to become a viable and sustainable enterprise. In comparison to other leaf fibres, Agave Americana fibres have a low density, high tenacity, biodegradability, low cast per unit volume, high strength, specific stiffness, easy availability, and high moisture absorption. These fibres are biodegradable and lengthy. As a result, we can consider this fibre as a long-term production and technical resource.

Index Terms— Natural material,Agave Americana composite, green material, textile fibre

1 Introduction

As a tropical country, India is endowed with a plethora of renewable resources from the plant kingdom. Agave blossoms only once during its life time and then dies. Agave plants are grown along railway line, road sides, river banks and as a hedge plant in dry land areas throughout the country. There are many plants in the kingdom that have varied applications, but humans are unable to use them owing to a lack of knowledge. Plants in the plant kingdom provide a variety of purposes. Agave Americana is one of the numerous sources of strong natural fibre in the plant kingdom. Agave Americana has a variety of applications, one of which being fibre extraction

Agave Americana, sometimes known as "Aloevera," is a cheaply available plant. It has a variety of applications, one of which is the extraction of fibre from the leaves. Because of the lack of understanding about Agave Americana fibre, it is employed in non-textile applications such as rope making and mat making.

However, study on Agave Americana fibre discovered that it has good features such as length, strength, and lustre, so it is employed in the textile industry to make fabric[2].

Cellulose fibreoffers a wide range of applications in a variety of industries, including automotive and electronics. These natural fibres can be utilised for noise-absorbing panels and insulation.

There are plenty of renewable resources obtainable from the plant kingdom, and a vast resource for different natural fibers viz.

Jute, Banana, Coir, etc., which are abundantly available in many parts of world. However, there are still a number of other vegetable fibers which have not been used as textile fibers. From the plant kingdom, one of the abundant sources of strong natural fiber is "Agave Americana". Agave Americana fibers are also called "Pita Fibers".

2. Extraction of Agave American Fibers

2.1 Intial stage of extraction

For fibre extraction, mature Agave Americana plant leaves are gathered from the field. A sharp cutting tool is used to cut away from the plant any lower leaves that are at an angle of more than 45° to the vertical. The leaves are harvested and brought to a factory where the fibre is extracted. Thorns on the leaf edges and the spine at the leaf tip are removed before extraction. The processes for extracting Agave Americana fibres from plant leaves are similar to those used for sisal fibre extraction[5].

Mechanical extraction, chemical extraction, and the retting process are the three main fibre extraction procedures. All extracted leaves are rinsed away before drying after fibre extraction using any of these procedures. The moisture concentration in fibre has an impact on fibre quality, hence proper drying is crucial. Artificially dried fibres are of superior quality than those dried in the sun. To avoid bleaching from direct sunshine, the fibres were dried in the shade. After that, the dry fibres are combed, graded, and put into bundles[4].

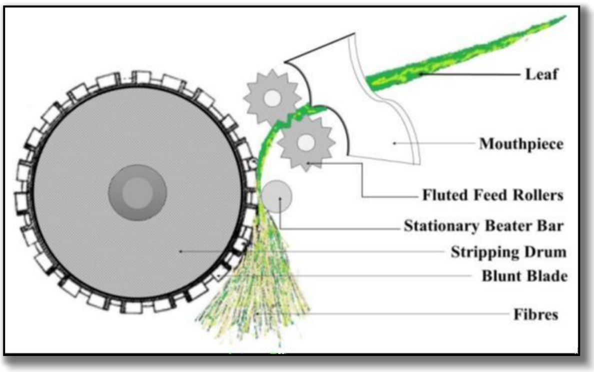

Fig. 1 – Fibre Decorticator

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2.2 Final Stage

The fibre is separated from the lignocellulosic biomass using a preferred decaying technique that does not damage the cellulose in the fibre. The microbial liberation of plant fibres from their environment is known as retting. It can take up to three weeks to complete the process. The non-fibrous cementing elements, primarily pectin and hemicellulose, are consumed by retting microorganisms. The degradation of the less resistant intercellular adhesive molecules gradually softens the leaves. The fibres may be easily separated from the leaves after the fermentation has reached the suitable level.

If the retting process is set to continue past this point, the quality of the fibres will deteriorate. Under-retting results in the partial removal of sticky components such pectin compounds, making fibre extraction problematic. As a result, to avoid fibre damage, the retting process must be closely monitored at regular intervals. Although natural retting takes longer, it is more cost effective.

Water retting and field or dew retting are the two most common types of retting. Plant leaves are immersed in water during water retting (river, pond or tanks). The crop is scattered in the field where rain or dew provides moisture for retting in field or dew retting. Fibers collected by water retting are more consistent and of higher quality than fibres retrieved by field retting[5].

Fig.2 – Agave Americana Fibres

2.3 Epoxy and hardener – (LY556 & HY951)

Epoxy resins are made up of a family of basic components and cured end products known as epoxy. Epoxy resins, also known as polyepoxides, are a type of epoxide-containing reactive prepolymers and polymers. Epoxy refers to the epoxide functional group as a whole. Epoxy resins can be reacted (cross-linked) with a variety of co-reactants, including polyfunctional amines, acids (including acid anhydrides), phenols, alcohols, and thiols, by catalytic homopolymerisation (usually called mercaptans). The cross-linking reaction is generally referred to as curing, and the co-reactants are referred to as hardeners or curatives. Polyepoxides react with each other or with polyfunctional hardeners to generate a thermosetting polymer with good mechanical properties and good thermal and chemical resistance. Metal coatings and composites are just a few of the possibilities for epoxy[6].

Fig 3 – Epoxy and Hardener

2.4 TiO_2 Titanium Dioxide – (As a Nanoparticles)

Titanium dioxide (TiO2) is a white, opaque, naturally occurring mineral that comes in a variety of crystalline forms, the most important of which are rutile and anatase. These naturally occurring oxide types can be mined to provide a commercial titanium source. Titanium dioxide has no odour and is highly absorbent. It's most important use in powder form is to serve as a frequently utilised white and opacity pigment. Titanium dioxide is used in porcelain enamels as a bleaching and pacifying agent, giving them brightness, hardness, and acid resistance. Because of its ability to absorb ultraviolet light, titanium dioxide is now utilised in cosmetics such as skin care products and sunscreen lotions, with claims that it protects the skin from UV radiation.

Titanium dioxide has a number of distinct properties that make it appropriate for a wide range of applications. It has a melting point of 1,843°C and a boiling temperature of 2,972°C, therefore it exists naturally as a solid, and it is insoluble in water even in particle form. TiO2 is an insulator as well. Titanium is a shiny white metal with a low density, high strength, and high resistance to corrosion[7].

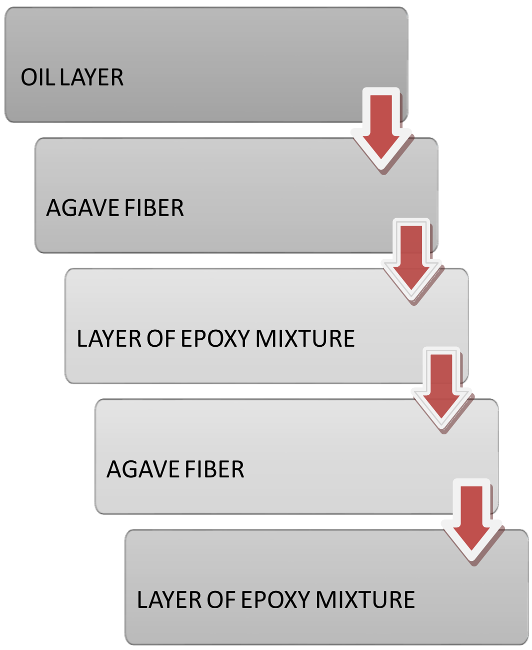

Fig 4 – Preparing specimen Flow chart

Fig.5 – Final Cured Specimen

Here we will be taking 60% of epoxy resin. Now adding the filler material to epoxy resin and mixing it with the help of glass rod uniformly. 0.1% of titanium dioxide (TiO_2) is added with respect to weight of epoxy resin that is 40%. Now take 10% of hardener with respect to weight of epoxy taken i.e., 25gms. By noting that hardener should be added after the addition of filler material in epoxy resin[8].

2.5 Cutting Process

When cutting thin strips of wood on a table saw, they often fall into the extra space in the throat plate around the table.
A Bandsaw (also written band saw) is a power saw with a long, sharp blade consisting of a continuous band of toothed metal stretched between two or more wheels to cut material. They are used principally in woodworking, metalworking, and lumbering, but may cut a variety of materials.
The blade itself can come in a variety of sizes and tooth pitches (teeth per inch, or TPI), which enables the machine to be highly versatile and able to cut a wide variety of materials including wood, metal and plastic[8].

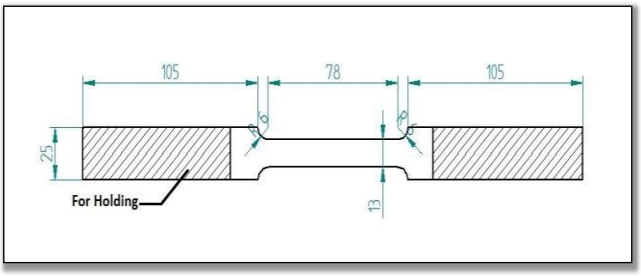

Fig.6 – Tensile Specimen

Fig.7 –Hardness Specimen

Fig.8 – Bending Specimen

3 TESTING RESULTS

3.1 Tesile test

Our prepared polymer composite specimen made of Agave Americana leaf fibre as the matrix, Epoxy resin as a reinforcement with TiO_2 as our Nanoparticles. We will be conducting three test on the specimen they are,
Tensile test according to Indian standard and bending test according to ASTM standard on Universal testing Machine.
Hardness test according to ASTM standard on Rockwell hardness testing machine[5].

Fig.9 – Tensile test on UTM (TUTE 60 T) Machine

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3.2 Bending testing

A bending test (also known as a bending tensile test) is a method of determining the bending strength and other critical properties of materials. Standardized, typically cylindrical specimens are placed in the centre of the checking fixture during bending testing. The sample is loaded with increasing force by the test punch, which goes down gently and at a steady pace, until it breaks or reaches the previously defined deformation. The breaking force is the maximum load applied during the bending test. The bending force and deflection values are recorded during the test. After that, the material properties are determined. Bending tests are used to extract information about a material's bending behaviour from a single-axis bending force[5].
We will be conducting bending test on UTM TUTE 60 T according to ASTM A370-20 standard.

Fig.10 – Bending test on UTM

3.3 Hardness testing

The Rockwell hardness tester is a machine that determines hardness by measuring the depth of penetration of a penetrator into a specimen under specific test conditions. A steel ball or a diamond spheroconical penetrator can be used as the penetrator. Hardness is a good predictor of ductility and wear resistance since it is strongly connected to tensile strength[6]. We will be conducting Hardness test on Rockwell Hardness Machine according to ASTM A 370-2020 standard.

Fig.11 – Hardness test on Rockwell Hardness

4.1 Tensile Results

The addition of the nanoparticle TiO2 increases the material's tensile strength, as we previously learned. As may be seen from the graph. The specimen was put through its paces on a Universal Testing Machine (UTM TUTE 60T). IS1608-2022 was used to conduct the test. The following outcomes have been observed

PARAMETERS	UNIT	OBSERVED VALUES
Maximum Load	KN	7.8
Tensile Strength	MPa	29.39
Initial Gauge Length	mm	80
Fianl Gauge Length	mm	81.56

Tab.1 Test Results

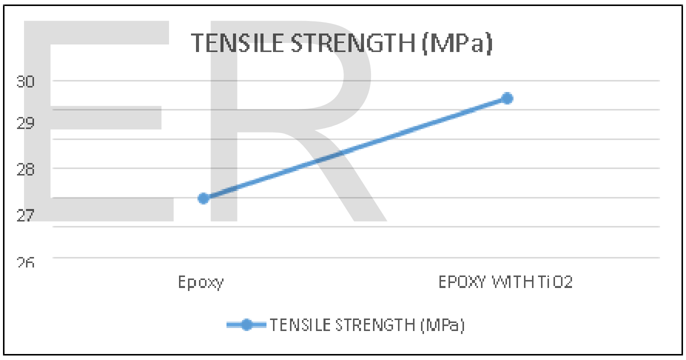

Fig.12 – Stress vs Strain

Fig.13 – Tensile test conducted on specimen

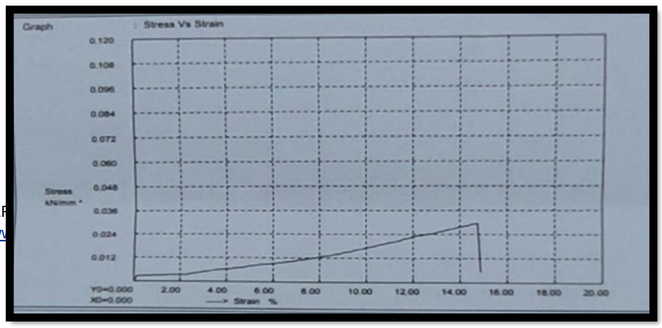

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Fig.14 – Tensile test report Graph

4.2 BENDING TEST RESULTS

The specimen for bending testing is prepared according to ASTM A370-20 standard and the test was carried on Universal Testing Machine (TUTE 60T) at room temperature. The thickness of the specimen is 13.19mm. The load was applied in the middle of the top surface of the specimen deforms.

Fig. 15– Bending Test conducted specimen

4.3 HARDNESS TEST

The specimen for Rockwell Hardness Testing is prepared according to ASTM A370 standard and the test was carried on Brinell Hardness Testing Machine at room temperature. The thickness of the specimen is 13.19mm. The load was applied in the of the top surface of the specimen which develops crack and specimen deforms.

5.1 J-OCTA SOFTWARE

J-OCTA is a multi-scale simulation software that predicts properties from the atomistic to the micrometre scale on a computer for research and development of a wide range of high- performance materials, such as resins, rubbers, nano composites, thin films, inks, and batteries, as well as drug discovery and pharmaceutical formulation in the life science field. J-OCTA can be employed in materials and life science research and development.

It can be used as a data creation tool for informatics and as a knowledge discovery tool to understand the mechanics of complicated events that cannot be comprehended by experimentation alone.

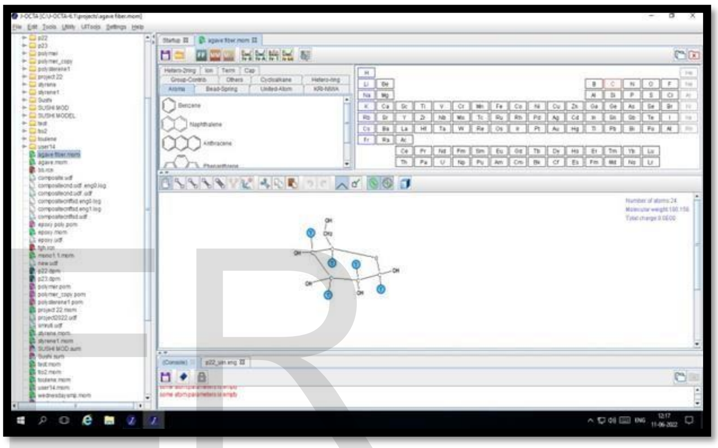
To enable cutting-edge research and development, it is also possible to connect simulators of various scales on a similar platform and combine data science capabilities. J-OCTA simulation has multiple simulation engines where we can model sub atomic to micro meter scales namely SIESTA, COGNAC, VSOP, PASTA, SUSHI, COGNAC DPD, MUFFINS, KAPSELS.

Using the mean field approach (SUSHI) and the dissipative particle dynamics method, estimate the phase separation structure and interface geometry of materials with varied molecular structures and block copolymers (COGNAC-DPD).

To begin the research, we modelled the essential components, such as epoxy, agave fibres, TiO2, and so on. We used the chemical structures of each component to determine the individual force field.

To assist OCTA/J-OCTA usage, JSOL offers a simulation commission service that involves estimating the physical properties of soft materials, typically resin or rubber polymer materials, as well as comprehending the material mechanisms.

A preliminary survey, modelling, input data production, simulation, and analysis of the simulation result are all included in the commission service. The input data for the simulation, as well as the final report, are provided by JSOL[9].



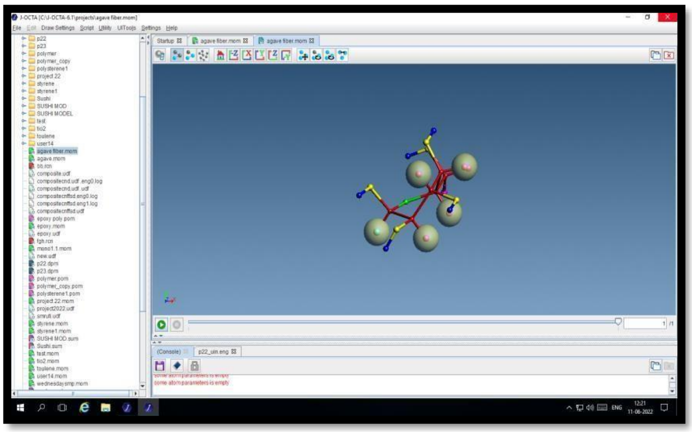
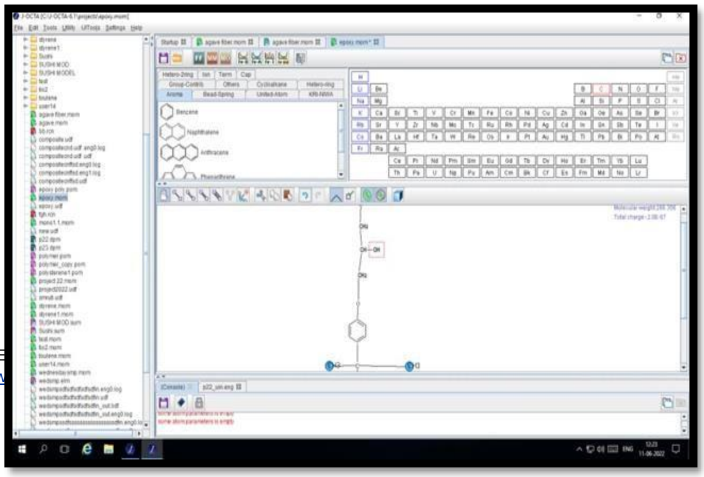


Fig.16 – Molecular structure of agave fiber



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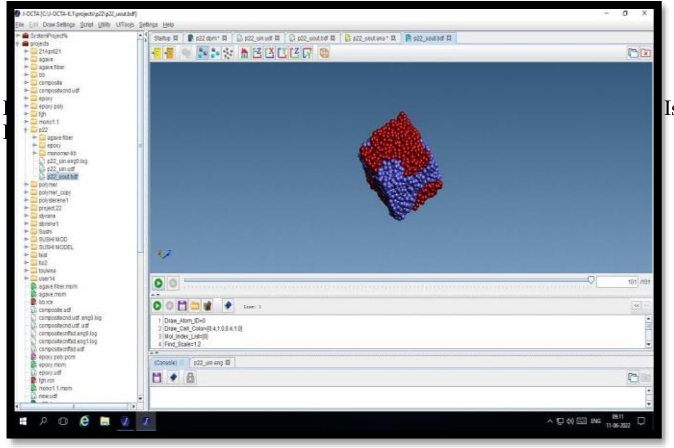

Fig.17 – 3D view of agave fiber

Fig.18 – Molecular structure of Epoxy resin

5.2 CALCULATIONS THE ESTIMATED INTERACTION

To obtain the parameter, estimate the SP value (solubility parameter) using the group contribution method, QSPR, or molecular dynamics.

The COGNAC-DPD (Dissipative Particle Dynamics) Engine was used to calculate the parameter based on the contact energy between coarse-grained segments and the coordination number utilising force field calculations or fragment molecular orbital computations. Which gave us the best results with the TiO_2.

Fig.19 - 3D view of the segment

5.3 CONCLUSION

Agave Americana leaf fibres can be used in technological applications such as reinforced composite materials, paper production, and so on, based on their qualities. Agave fibres improve the composite's tensile strength and attachment to polyester and polyepoxyde matrixes over glass fibres. In fact, given the same filling up coefficient of fibres, the resistance of agave fibre-reinforced composites is approximately identical to that of glass fibre-reinforced composites. Based on their intriguing mechanical behaviour in polyester and polyepoxyde matrixes, we suggest that agave fibres can be used to strengthen composite constructions. And the addition of the TiO_2 gave the highest strength, still that can be increased by increasing the weight factor of the nanoparticle(TiO_2).The major goal of this research was to create a sturdy material that could withstand a lot of weight while still being biodegradable. The specimen was discovered to have excellent mechanical characteristics. The specimen should be constructed with the greatest accuracy possible, without any pores or air bubbles, in order to improve tensile strength.

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