ANALYSIS OF EPOXY COMPOSITES REINFORCED WITH THE EXTRACTION OF MICRO-CELLULOSE FROM HS FIBER

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Abstract: In this paper, we analyse the mechanical properties of epoxy composites reinforced with micro-cellulose extracted from the H. sabdariffa fibers. The extracted micro-fillers from the H. sabdariffa fibers are processed via chemical treatment and it is utilised in various applications. The experimental results are conducted to test the efficacy of the extraction via its tensile nature, flexural nature, impact of the material. The results show a superior behaviour with various filler loadings. Further the internal structure is investigated thoroughly and it shows an improved tensile nature and rigidity.

Keywords: Epoxy Composites, Micro-Cellulose, HS Fiber, Extraction.

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INTRODUCTION

In recent years, there has been an increase in the demand for products that have been created using renewable resources such as those that are described above (not based on petroleum, biodegradable, or carbon availability in nature) [1, 2]. For example, the demand for products that have been created using renewable resources such as those that are described above has increased.

In light of the information that has been presented thus far, scientists from all around the world are doing research in order to figure out how organic components might be utilised as reinforcement elements within the polymer matrix. Their long-term objective is to use this combination in the manufacturing of engineered buildings. Because of this, natural fibre composites have witnessed a surge in popularity in the engineering business over the past few years [3]. This is a direct consequence of the aforementioned factor.

Composite materials that are manufactured from natural fibres have a wide range of potential applications, and these applications might fall into either the static or dynamic categories [4]. These applications can be found in the construction, electronic, food packaging, electronic, and sports equipment industries, among others. To be more specific, the automotive industry has made extensive use of composite materials that are made from natural fibres for a wide variety of car parts, such as seats (made from coconut fibre rubber latex composites), door panels (made from fax-sisal fibre mat reinforced epoxy composites), door trim panels (made from sisal mat reinforced polyurethane composites), and doors (made from kenaf fibre reinforced composites) [3, 4]. These composite materials have many advantages over traditional metals and plastics,

Researchers in the field of materials science are currently focusing their attention on improving the mechanical properties of organic microfiller-reinforced composites. This is being done because organic microfiller-reinforced composites are superior to short and long fibre-reinforced polymer composites [5]. When compared to their synthetic counterparts, the costs of making organic fillers are much lower [6, 7].

A considerable number of studies have been conducted on the application of plant fiber-reinforced polymer composites (short fiber/woven mat). On the other hand, research with reinforcing microcellulose fillers has not yielded the same kinds of effects as the previous types of research [8]. As a consequence of this, there is still a need for further research into the potential application of fillers at micro-level that are derived from natural fibres.

A paradigm shift in thinking has lately taken place in the scientific community in the direction of the production of micro-cellulosic fillers from novel sources of biomass for

widespread application in polymer composites. Cellulose, a form of biopolymer that is created by consistently linking D-glucopyranose, makes up the vast majority of plant fibres [9]. Cellulose is a sort of biopolymer. The cellulose that was employed in this process could have originated from a wide range of different materials, such as wood, plant fibres, agricultural waste, and so on.

Researchers in the field of material science have focused a lot of their attention on cellulosic microfillers due to the fact that these fillers meet the requirements of industry while also being inexpensive to produce, biodegradable, and derived from resources that are continually renewed. The ability of micro-fillers to increase the mechanical, thermal properties and surface morphological features of polymer composites is what sets them apart from other types of fillers [10].

There are a number of approaches that can be used in order to separate HS fillers from the plant sources from which they originate, some of which include chemical, biological, mechanical, and hybrid techniques. One of the less expensive ways that has the potential to successfully generate HS microfillers is chemical treatment. This technique works by eliminating as much non-cellulosic material as possible from the natural fibre while simultaneously boosting the natural fiber ability to resist moisture and increasing the size of its crystalline structure. An integrated process that consists of alkalization, chlorination, and hydrolysis is one of the most common chemical treatments that is utilised in order to get rid of the components of the fibres that are not made of cellulose matter. This is one of the reasons why acidified chlorination is one of the most widely used chemical treatments. The polymerization of the cellulose chains is also broken, which results in the fibres having a diameter that is somewhere in the micron range. This technique possesses a number of enticing advantages, not the least of which is its low production cost and its generation of particles in the micron range through a process that operates continuously and uses just a minute quantity of acids.

In this paper, we analyse the mechanical properties of epoxy composites reinforced with micro-cellulose extracted from the H. sabdariffa fibers. The extracted micro-fillers from the H. sabdariffa fibers are processed via chemical treatment and it is utilised in various applications.

RELATED WORKS

Stalin et al. [11] developed a composite material by consolidating vinyl ester with seed filler. This material was used to make the composite. A compression mould was used to give shape to the composite material. Research was conducted to determine the tensile, flexural, and impact strengths of composites that contained tamarind seed. Their calculations suggest that by increasing the amount of filler in the matrix by 15% points, the tensile strength of the material can be increased by 39.5%, the flexural strength can be increased by 55.5%, and the impact strength can be increased by 21.5%.

When producing date palm seed powder for use as a reinforcement in a compression-molded vinyl ester polymer matrix, ball milling was used, as was the case with the research that Prasad et al. [12] carried out. When a seed powder equal to 30% of the total weight of a composite is added, the thermal and mechanical properties of the composite are greatly improved.

Vinod et al. [13] evaluated the properties of jute fiber-reinforced epoxy composites that are either manufactured with or without the addition of Calotropis gigantea stem particles (range: 5–10% wt). They found that the addition of the stem particles did not affect the characteristics of the composites. They carried out research and found that the maximum flexural strength of the Calotropis gigantea stem composite is 195.19 MPa, while the maximum tensile strength of the composite is 48.73 MPa. This information was gleaned from the findings of the study. This information was uncovered during the course of study. Also, some other works such as [16[17], [18] have did a similar study on the composite materials.

Vignesh et al. [14] are interested in the manner in which these characteristics are influenced. They came to the conclusion that double-layered Indian mallow fibre reinforced polyester composites with sawdust filler in the longitudinal direction of the yarn mat had the best tensile strength.

Santhosh et al. [15] also investigated an alkali-treated epoxy composite with 5% wt.% rice husk particles. It is discovered another interesting fact about the composite material: its flexural strength was higher than its tensile strength. According to research that has been done on the topic, increased improvements in the mechanical and thermal properties of the materials have been proven to result with the introduction of cellulosic filler material into polymer composites. According to works that have been published, research into the mechanical, thermal, and morphological behaviour of polymer composites that have been supplemented with waste cellulosic filler (derived from agricultural waste) is still possible, and it could help partially meet the demand that exists all over the world.

PROPOSED MODELLING

Epoxy was used as the matrix, and HS fibre was introduced into the mixture in order to provide reinforcement for the finished product. Both the matrix and the reinforcement are made out of different materials. The matrix is made out of Araldite CY-230, and the reinforcement is made out of Hardener HY-951. With the assistance of NaOH and $NaClO_2$, it is possible to remove the cellulose that is present in raw fibre.

In order to determine whether or not H. sabdariffa fibres have the capacity and potential to enhance the mechanical characteristics of polymeric materials, it is very important that we have a good understanding of the features that these fibres possess. The morphology and cross section of the fibres, the diameter and density of the fibres, the quantity of moisture that is contained inside the fibres, how well they absorb water, chemical and functional groups, and thermal studies are some of the attributes that are being analysed.

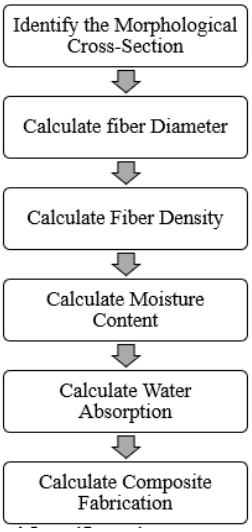

Figure 1: Proposed Framework

Morphology Cross section

A field emission scanning electron microscope was used to examine the surface morphology of H. sabdariffa fibres that had not been treated as well as those that had been treated. The utilisation of the FE-SEM ensured that the environment would remain unchanged. Before the microscopic analysis was carried out, a coating of gold that had been sputtered on had been applied in order to boost the conductivity of the fibres.

Fiber Diameter

The diameter of both unprocessed and processed H. sabdariffa fibres was measured using a micrometre evaluation (brand name: Mitutoyo) at three distinct locations along the length of both sets of fibres. The measurements are taken in the same direction as the length of the fibres. The results of measurements that are carried out on an average of 120 distinct fibre samples are provided. We decided to measure the diameter with an FE-SEM to ensure accuracy.

The utilisation of the FE-SEM ensured that the environment would remain unchanged. Before the microscopic analysis was carried out, a coating of gold that had been sputtered on had been applied in order to boost the conductivity of the fibres.

Fiber Density

By applying the values into Equation 1, which can be seen down below, we are able to determine the fibre density in a manner that was compliant with the ASTM D792 standard. In this Archimedean approach, the first step was to determine the mass of the container, denoted by M1.

The container was placed within a calibrated clear glass tube that contained a predetermined volume of water. A series of calculations are carried out in order to establish the amount of water that was ejected (V1). After determining the amount of additional weight that the container gained as a result of the addition of H. sabdariffa fibre (M2), the container that held the fibres was submerged in the calibrated, transparent, measuring glass tube that held the same volume of water as before. This was done in order to determine how much weight the container gained as a result of the addition of the fibre. To figure out how much water was thrown out, a series of calculations are done (V2).

Density=Mass(M2-M1)/V m/cm^3

Moisture Content

In order to calculate the relative amount of moisture that was present in the fibres, the following equation was utilized: After preparing five identical samples, the average was then calculated using the results of the experiment. The samples are weighed on a digital scale that had a resolution of 0.001 grammes, and the results of the measurements are written down (M1).

They spent 24 hours being roasted in an oven that had been warmed to one hundred degrees Celsius. After the passage of twenty-four hours, the samples are collected, and the histories of each of them are documented. After taking the samples out of the oven, they are weighed every two hours until there was no indication that their weight had changed, at which point the final weight was recorded (M2).

Moisture content = ((M1-M2)/M1) x 100 %

Water absorption

In order to establish the percentage of water absorption that was required in order to comply with ASTM 570, the following calculation was utilised: After preparing five identical samples, the average was then calculated using the results of the experiment. The samples are weighed on a digital scale that had a resolution of 0.001 gram, and the results of the measurements (M1) are noted down.

They are left in this position for a whole day with their heads submerged in a beaker that contained distilled water at ambient temperature. After a total of twenty-four hours, we took the samples out of the water, let the fibre air dry fully, and then weighed the samples within sixty seconds of taking the samples out of the water (M2).

Water absorption=((M2-M1)/M1) x 100 %

Composite Fabrication

The hand-lay-up process was utilised in order to produce the composite laminates that are subjected to the test. This allowed for the most accurate results possible. In the beginning, the HS fibre micro-cellulose was extracted from the plant through the use of the steam explosion process. Raw fibres are sliced after first being cut into lengths of 10 centimetres and then being dried in a hot air furnace at a temperature of 50^o C for 2 hours. Following that step, the fibres that had been cut are immersed in a solution of NaOH that was maintained at room temperature. Following the application of an alkaline solution, the fibres

underwent a thorough washing with distilled water before being subjected to a steam explosion as the final step in the process. In order to treat steam explosion fibres for an hour in a hot air oven containing a $NaClO_2$ solution, the temperature was set to fifty degrees Celsius, and the treatment lasted for the full hour. After being cleaned with distilled water, the fibres are then sterilised in an autoclave by being subjected to a steam explosion for three hours at temperatures and pressures of around 120 degrees Celsius and 15 pounds per square inch, respectively. The fibres are washed in distilled water until they reached a pH balance that was neutral, and then the washing process was complete. Following the steps outlined above to obtain micro-cellulose, it was combined with a high-density epoxy matrix and then subjected to two hours of vigorous physical agitation in order to achieve a dispersion that was consistent throughout. After the liquid had been poured in, the mould was sealed by placing a plate of wood across the top in a parallel fashion. This completed the process.

RESULTS AND DISCUSSIONS

The actual tensile strength can be found in Figure 2 - Figure 7 depicts how the addition of micro-cellulose reinforcement affects the mechanical properties of epoxy composites. This demonstrates that the capacity of composites to sustain loads can be increased by including HS fibres in the material. Because of this, there is a greater interaction between the microcellulose and the epoxy as a result of the inclusion of the HS fibres. This is the reason for this finding. If a greater wt % of microcellulose reinforcement is utilised, then this is not a major concern that needs to be addressed. In order to successfully transmit the load from the fibre to the matrix, the interfacial strength of the material must provide the necessary assistance. The form of the surface of the fibre itself also has some kind of influence on the interfacial strength. Because the epoxy resin causes the fibres to become wet and also develops chemical linkages with the fibres, the interfacial strength is strengthened as a result of this interaction.

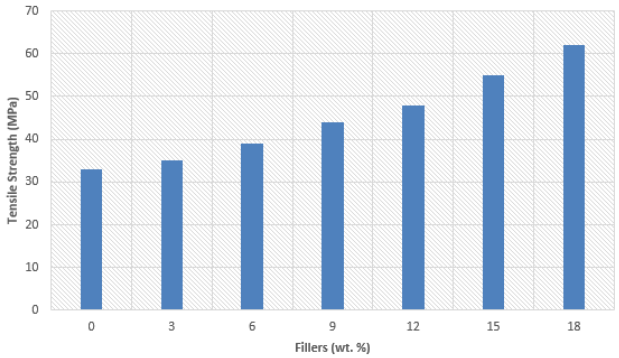

Figure 2: Tensile Strength vs. Filler ratio

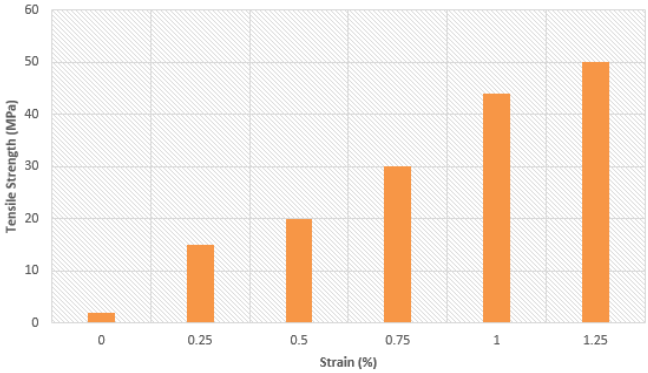

Figure 3: Tensile Strength vs. Strain (%)

This suggests that the tensile characteristics improve up to a fibre loading of 30 wt.%, but then begin to deteriorate when the fibre loading is increased to 40 wt.%. The poor tensile properties present in approximately 40% of micro-cellulose are responsible for the agglomeration of the cellulose, which can be traced back to the original cause.

When they are loaded, the composite load-bearing capabilities are diminished as a direct consequence of this phenomenon. When there is a low proportion of fibre weight in a composite, the mechanical properties of the composite suffer because the individual fibres are unable to transfer the load that they are under to one another. This causes the mechanical characteristics of the composite to suffer.

When there are adequate fibres present for their active participation in load transformation, it is possible to produce better results by increasing the fibre loading to 30% of the material total weight. This is possible when there are adequate fibres present for their active participation in load transformation.

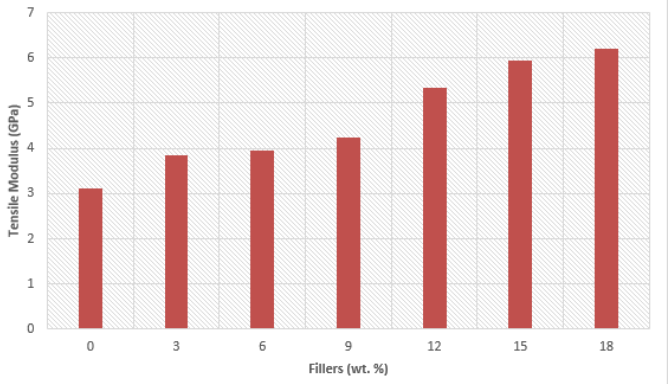

Figure 4: Tensile Modulus vs. Filler (%)

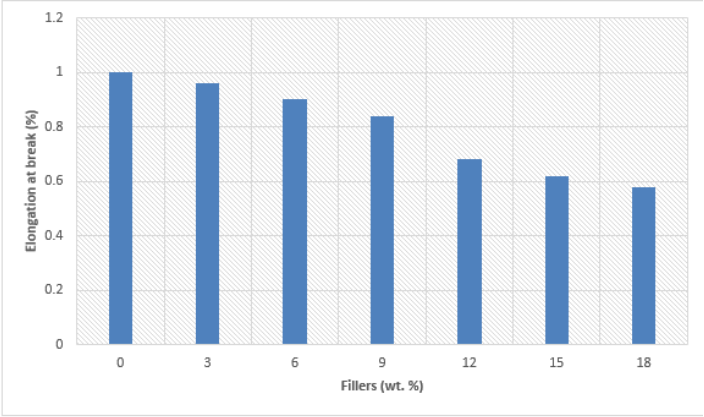

Figure 5: Tensile Modulus vs. Filler (%)

A number of parameters influence the degree to which plant fiber-reinforced acrylics exhibit their robust properties, including the length of the fibers, their orientation, the number of fibres present, and the interfacial connection that exists between the fibre matrix and the fibers. There is a school of thought that contends that the presence of hydroxyl (OH) groups in natural fibres confers upon such fibres a greater receptivity to the process of moisture absorption. As a consequence of this, the interfacial connection between the hydrophilic fibres and the hydrophobic polymer matrix is tenuous, and the fibre itself has low wettability. Mercerization is an effective method for generating efficient interfacial contact between fibres and polymers because it imparts hydrophobic properties on the fibers.

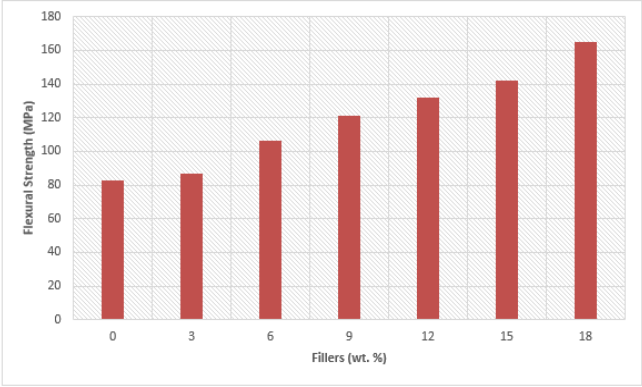

Figure 6: Flexural Strength (MPa) vs. Filler (%)

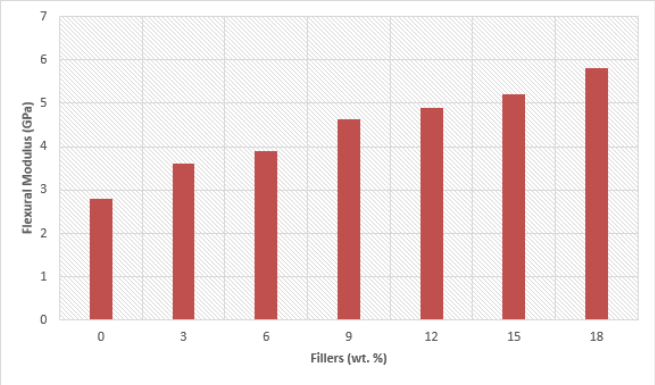

Figure 7: Flexural Modulus vs. Filler (%)

Through the use of a chemical treatment, it is possible to considerably enhance the interfacial connection that exists between the fibres and the matrix. The flexural and impact strengths of the material are significantly improved when mercerized H. sabdariffa fibres are added to PMMA denture base resins. These advantages are most noticeable at 7.5 wt.% and 3 millimetres of fibre length. H. sabdariffa fibres are dispersed throughout the polymer after first being pre-impregnated with the monomer.

This led to an increase in the flexural strength of the material. The fibre surfaces are better able to develop an intimate connection with the polymer matrix as a result of the pre-impregnation process, which enhanced the interfacial interaction between the fibres and the acrylic resin. This improved connection was made possible as a result of the fact that the fibres are better able to develop an intimate connection with the polymer matrix.

The ultimate bond strength between the H. sabdariffa fibres and the acrylic was used to calculate the capacity of the matrix to transfer load to the fibres. In this way, the capacity of the matrix to transfer load to the fibres was determined. It is possible that the low fibre concentration used is to blame for the decrease in strength qualities observed in the reinforced groups constructed with either 2.5 or 5 wt.% H. Sabdariffa fibers. These groups had either 2.5 or 5 wt.% H. sabdariffa fibre reinforcement. Failure at the mechanical level is caused by a severe disruption in the molecular link that exists between the individual polymer chains. This disturbance may have been brought on by a number of different sources.

Agglomeration, which is also known as increased fiber-to-fiber contact, may be to blame for the loss of strength that was observed in the acrylics that are reinforced with 10% H. sabdariffa fibre. Agglomeration is to blame for this predicament because it inhibits stress from being passed to the reinforcing fibres, which ultimately results in a loss of strength.

A portion of the polymer matrix strength will be diminished if excessive amounts of fibre are employed, which will cause the matrix to lose some of its overall strength. After the H. sabdariffa fibres and the acrylics had been thoroughly diffused throughout the resin mass, it was possible to generate interfacial bonding between the two different types of material. Denture base resins are made stronger by filling in holes and stopping cracks from getting bigger.

CONCLUSIONS

In this study, epoxy composites that are strengthened with micro-cellulose derived from HS fibre are put through a series of tests to evaluate their tensile strength, hardness, and impact resistance, among other possible mechanical qualities. The mechanical properties of epoxy composites are modified in a way that was distinct from one another based on the wt.% of cellulose, according to the study findings. The experimental results are conducted to test the efficacy of the extraction via its tensile nature, flexural nature, impact of the material. The results show a superior behaviour with various filler loadings. Further the internal structure is investigated thoroughly and it shows an improved tensile nature and rigidity. The results showed that the agglomeration effect made the mechanical properties of the composites worse when they are strengthened with 40% micro-cellulose.

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