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Mechanical Behavioral Analysis of Sugarcane Bagasse, Coconut Fiber and Kevlar Fiber Reinforced Composite with Micrographs

V. Pugazhenthi[1,*], P. Ashok kumar[2], R. Rajappan[3], S. Vandaarkuzhali[4], P. Gurusamy[5], K.R. Rekha[6], N. Ramanan[7]& B. Somasundaram[8]

Abstract

Asbestos and alloys are materials that are frequently used as brake pads; however, because these materials pose risks to human health and the environment, including lung cancer, it is necessary to replace the materials used in brake pads. In place of the current brake pads, composite fibers such as kevlar, sugarcane bagasse, and coconut are studied in this study. The procedure of manually laying up composite molding is used to create the fibers. Tests for tensile, compression, wear, double shear, and Dynamic Mechanical Analysis (DMA) were used to examine the mechanical behavior of the fibers, and a scanning electron microscope (SEM) investigated the fracture surfaces. Natural fibers exhibit excellent adhesive qualities, great ductility, and hardness based on the outcomes of experimental testing. This indicates that the fibers possess the necessary mechanical strength, wear resistance, and thermal stability to perform effectively as friction materials such as in brake pads or clutches where they can withstand high stress and resist degradation during operation. Friction wear can be reduced by analyzing inter-delamination factors through double-shear tests, which show higher shear strength. The DMA test results showed that natural composites have high tangential and loss modules in cyclic temperatures, which contributes to an improvement in their ability to handle high temperatures and friction. The brake pad models were the subject of the FEA analysis. Finally, the performance of polymer-based brake pads is compared with the results from existing brake pad tests.

***Author for Correspondence**
V. Pugazhenthi

[1,2]Assistant Professor, Department of Mechanical Engineering, Mailam Engineering College, Mailam, Villupuram, Tamil Nadu, India
[3,4]Professor, Department of Mechanical Engineering, Mailam Engineering College, Mailam, Villupuram, Tamil Nadu, India
[5]Professor, Department of Mechanical Engineering, Chennai Institute of Technology, Kundrathur, Chennai, Tamil Nadu, India
[6]Assistant Professor, Department of Mechanical Engineering, Achariya College of Engineering and Technology, Villianur, Puducherry, India
[7]Assistant Professor, Department of Mechanical Engineering, Sri Jayaram Institute of Engineering and Technology, Chennai, Tamil Nadu, India
[8]Assistant Professor, School of Mechanical Engineering, REVA University, Bangalore, Karnataka, India

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INTRODUCTION

With an abundance of natural fibers, including jute, coir, sisal, pineapple, ramie, bamboo, and bananas, India has focused on creating natural fiber composites primarily to explore prospects for value-added applications. Such natural fiber composites are ideal as wood alternatives in the housing and building industries. India's approach to the creation of natural fiber composites is twofold: avoiding the depletion of forest resources and delivering strong economic returns from natural fiber production. After solving the problems of the aerospace industry, innovations in composite materials have cascaded down to suit the needs of household and also industrial uses. Because of their tremendous strength-to-weight ratio, composites are a wonder material, stiffness, and low weight, have greatly outperformed traditional materials like wood, metal, and so on. To lower the price of unprocessed materials, material scientists worldwide concentrated on natural composites strengthened with pineapple, coir, sisal, jute, and other materials.

Jute, Bamboo, Banana, Pineapple, Coir, Ramie, Sisal are the natural fibers used to develop new kinds of composite materials and support materials science engineering and the environment. The natural fiber composites are more suitable for engineering than all other commercial sectors. Natural fibers' accessibility in India is reasonably good, and it is mainly focused on two categories: one is to save the forest resources, and the other one is the revenue from these fibers. These types of fibers are not only used in the aerospace sector, but additionally, they have been applied in both home and industrial settings [1]. Composite materials replace materials like metals and wood because they are lightweight, have a high strength-to-weight ratio and have superior rigidity. Composites made from natural fibers offer economic benefits by reducing the cost of raw materials, lowering energy consumption during manufacturing, and providing a sustainable alternative that minimizes dependency on expensive synthetic fibers in industrial applications. Everybody in the industry is working to create the best products possible using inexpensive, environmentally safe, and biodegradable composite materials that don't harm the environment. Bio composites made from various kinds and forms of natural fibers derived from biomass have been used in numerous industrial applications to reduce the environmental impact [2].

The current situation calls for the appropriate use of such cheap, readily available, renewable, and biodegradable biomass material for the manufacture of useful products, regarding the economy and the environment. The uses of natural fibers taken from coconut trees as polymer matrix reinforcements are constrained, nevertheless. As a result, it becomes necessary to obtain coconut tree fibers with outstanding qualities for use as polymer matrix reinforcement. In this regard, an inflorescence, a natural fiber found in coconut trees, has been identified, and attempts have been made to employ it in place of composites made of synthetic fiber-reinforced polymers for automotive application components. The high density and non-biodegradability of synthetic fiber-reinforced polymer matrixes are just two of their drawbacks; they also cause other significant problems like waste management and the depletion of fossil fuels. Finding a sustainable and biodegradable supply of fibrous materials, specifically natural lignocellulose fibers that can be supplemented with a polymer matrix, is therefore necessary [3].

Numerous scientists have studied natural fibers extracted from various plants, including kenaf, banana, sisal, and snake grass. In addition to having superior mechanical and thermal properties and a low density, natural fibers derived from plant sources can also be extracted using straightforward processing methods. Artificial fibrils are being largely replaced by plant-based fibers made from natural fibers that are derived. Glass and coconut fibers are used as reinforcements in the polyester matrix. The impact of silane modification applied to coconut sheath fiber post-mercerization treatment on the final composites mechanical characteristics was examined [4]. The composites mechanical characteristics were studied, and the results were obtained from flexural, impact, and tensile strength. In this study, the coconut fiber reinforcements showed better results as compared with glass fiber. Alkali and silane treatments improved the adhesion between the fiber and matrix and enhanced the hydrophilic properties of the fibers [5]. The 0 to 20% weight percentage of alkali-preserved bagasse fiber reinforced composites with liquid cashew shell prepared by the compression molding process. In this study, 15% of alkali-treated bagasse fiber-reinforced samples showed better results, and the study analyzed how the percentage of fiber decides the properties of the composite [6]. They reported that high-density polyethylene/sugarcane bagasse composites are fabricated by the compression molding process. The sample result shows better mechanical properties. These materials are preferred because of their exceptional strength and low weight. Recently, composite materials have involved a lot of interest from a range of manufacturing, including transportation, aircraft, and the military [7]. In general, composites have got high strength-to-weight ratio and the strength is 5 times better than steel. Kevlar fibers enhance reinforcing, in addition to carbon and glass fibers [8]. Furthermore, high-performance epoxy resins function on form in the matrix phase of composites [9].

Many processes have been used to produce the Kevlar composite; a few of these are covered below. The first fiber-reinforced thermoset polymer composites were made by hand lay-up reported that the widespread environmental factors of mechanical stress, heat, light, high-energy radiation, chemicals, or biological attacks would decrease the performance of the kevlar fiber instead of its better output [10–11]. Examined that the kevlar- reinforced composite materials exhibited unstable properties when the composite coupons were subjected to shear and compressive stresses. Reported that the Kevlar has a low intermolecular hydrogen bond force, and transverse strength, and due to its high benzene ring count, the fibers are broken easily. Studied the mechanical properties of the Kevlar-E glass, then the basalt-E-E glass hybrid composite by resin transfer molding with various configurations of the laminates [12–14]. From the research work, it was stated that the basalt-E- glass hybrid composite has shown poor strength as compared with the Kevlar-E glass hybrid composite. However, the electrical resistivity is as good as the Kevlar-E glass hybrid composite investigated the kevlar and flax fiber hybridization, and the results show that the Kevlar fiber exhibited non-linear behaviour and anisotropy [15]. The Kevlar fiber shows the compression weakness, as that of similar behavior was observed in flax fiber as well. Hybrid fiber composites were prepared by using carbon-glass and then carbon-Kevlar fiber at dissimilar carbon fiber stacking sequences [16–17]. Tests were conducted to evaluate the influence of carbon fiber on the final product fabricated using Vacuum Assisted Resin Transfer Moulding (VARTM). The mechanical properties of the carbon fiber were affected, which was derived from the results of tensile and bending tests [18]. The study investigated a hybrid fiber epoxy composite reinforced with glass, Kevlar fibers, and nano clay. The developed composite thermal and dynamic mechanical analyses were carried out. From the results, the weight of the composite is drastically reduced to 68.8%, and the temperature reaches 800°C. For the created composite, the glass transition temperature needed also to be raised. This is because both the glass and other fibers are aligned in the same direction, allowing them to share the load more effectively and improve the composite's overall strength and performance [19].

MATERIALS AND METHOD

Assortment of Raw Materials

Natural fiber (bagasse), Kevlar fiber, epoxy resin, hardener, and sodium hydroxide are the raw materials employed in this experiment. One residue that is frequently produced in large quantities in the agro-industry is sugarcane bagasse. After the sugarcane is crushed and its juice extracted, a fibrous residue of cane stalks is left behind. Bagasse often ranges in color from gray-yellow to light green. It is heavy and has a very uneven particle size distribution. Two different cellular elements make up the underutilized, renewable agricultural resource known as bagasse, which is made from sugarcane waste. The first is a fibrous, rather lengthy, thick-walled fraction that is made up of fibro vascular bundles scattered throughout the stalk's interior and the rind. The second is a pith segment made beginning with the ground tissue's thin-walled cells. The main chemical constituents of bagasse are cellulose, hemicellulose, and lignin. About 70% of the total chemical ingredients in bagasse are made up of cellulose and hemicellulose, which are found in the form of hollow cellulose. Lignin is another significant chemical component found in bagasse. Lignin serves as both an energy storage system and a binder for the cellulose fibers. Figure 1 shows the common depictions of the sources of imposed composite materials.

Dupont's para-aramide fiber is marketed under the brand Kevlar. Kevlar Aramid fiber was discovered in 1965. A DuPont research scientist developed many Para-oriented aromatic polyamides. In 1972, DuPont started marketing Kevlar Aramid fiber. "Aramid" is a broad term for a manufactured fiber whose fiber-forming substance is a long-chain synthetic polyamide with at least 85% of the amide linkages directly attached to the two aromatic rings, according to the U.S. Federal Trade Commission. Poly (p-phenylene terephthalamide) is the building block of Kevlar fiber. Kevlar is an organic fiber that is a member of the aromatic polyamide family. Kevlar's unique properties include its high strength, high modulus, toughness, and thermal stability. It was developed for demanding industrial and high-tech applications.

Figure 1. Pictorial view of (a) Sugarcane bagasse fiber, (b) Coconut fiber and (c) Kevlar fibre.

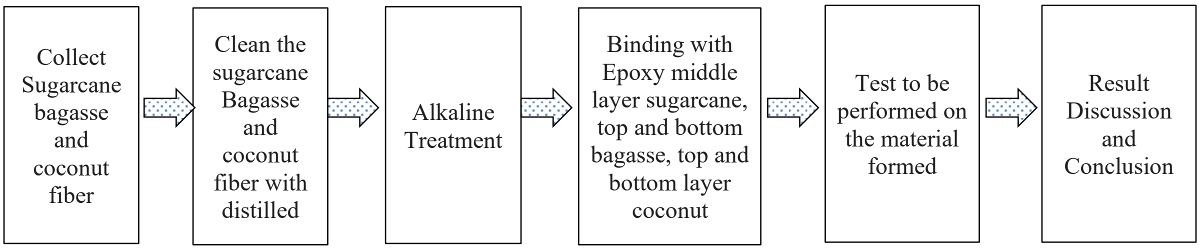


Figure 2. Research methodology.

Figure 3. Coconut fiber obtained after purification with distilled water.

These days, a large range of Kevlar is produced to meet the needs of various end users. Figure 2 depicts the research process for this suggested study, whereas Figure 3 shows the coconut fiber that was obtained following cleaning with distilled water.

Coir is made from the husks of coconuts. The fibers are first separated, spun into yarn, and then woven to make floor coverings, rugs, ropes, and other items. The fiber is extracted using a variety of conventional and modern methods, depending on the location of coir production. The coconut husks are separated from the coconuts and soaked in saline rivers or lagoons for a maximum of 10 months in order to extract the coir fiber. This is a time-consuming and labor-intensive method. Anaerobic fermentation occurs when the husks are submerged, softening and separating them. After that, the fibers undergo hand cleaning, drying, and washing. The purest white fiber suitable for spinning and weaving is produced by this age-old retting method. The collected sugarcane bagasse and sugarcane fiber obtained after purification with distilled water are revealed in Figure 4.

The soaking time can be shortened via mechanical methods. The husks are crushed, and their fibers are dispersed after five days of soaking in water. The short, woody portions are separated from the coarse fibers using drums, and they are then cleaned, dried, brushed, and washed. These processes are becoming more ecologically friendly as manufacturers concentrate on producing consistently high-quality goods.

Figure 4. Collected sugarcane bagasse and sugarcane fiber obtained after purification with distilled water.

Table 1. Chemical composition of sugarcane fiber.

Alloying Elements	Cellulose $(C_6H_{10}O_5)n$	Hemi cellulose	Lignin ($C_{18}H_{13}N_3Na_2$ O8S2)	Pectin $(C_6H_{10}O_7)$	Fat &Wax	Water Soluble
% of content	77.77	10	6.8	2.9	0.90	1.73

Table 2. Chemical composition of kevlar fiber.

Alloying Elements	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	TiO_2	B_2O_3
% of content	55.5	13.4	0.40	23	4	0.6	5

A linear chain of several hundred to many thousands of covalently bound D-glucose units makes up the organic molecule known as cellulose, a polysaccharide with the formula. Hemicelluloses are an essential structural element of the basic cell walls of green plants, several types of algae, and oomycetes. They are present in nearly all terrestrial plant cell walls in addition to cellulose. Cellulose is crystalline, robust, and hydrolysis- resistant. In addition to being branched and shorter than cellulose, hemicelluloses also have a tendency to crystallize. The entire chemical composition with the various percentages of elements also mentioned in Tables 1 and 2.

Testing and Experimental Methods

Sugarcane Bagasse and Coconut Fiber Obtained After Alkaline Treatment

The Kevlar-epoxy hybrid composites were made by the hand layup method. There are two phases in this procedure. The initial stage involved combining the epoxy resin with the sugarcane and coconut fiber layer microbeads at the appropriate volume while gently swirling to ensure even mixing. Once the combination of sugarcane and coconut fiber was combined, it was carefully swirled until it was homogenous. The sugarcane and coconut epoxy mixture was then blended with the curing agent and gently stirred until the degassing process was complete. Next, the final colloidal suspension was poured into a wax-coated silicon rubber mold lined with 30% Kevlar fiber. The composites were finally post-cured at 80°C (Tg zone) for 2880 minutes following 1440 minutes of curing at room temperature [11].

Preparation of testing samples

The testing samples were prepared by the moulding plate into test specimen in the way of abrasive water jet machining (AWJM) as shown in Figure 5. The AWJM technique creates regions with different surface characteristics according on the thickness of the material. The main cause of the variations in kerf widths that take place at the material's entrance and exit in the form of conicity or taper angle is the dispersion of the water jet's kinetic energy. The sample 1 refers that the combined form of Hemp fibre, Sugarcane fibre and GFRP. The middle layer of GFRP is completely sandwiched with the inclined HEMP fibre layers with uniform thicknesses. Likewise, the arrangements of all fibre elements can here located layer wise with proper thickness in sample 2 and 3 as mentioned in Figure 6 (a), (b) and (c). Table 3 displays the prepared composite compositions.

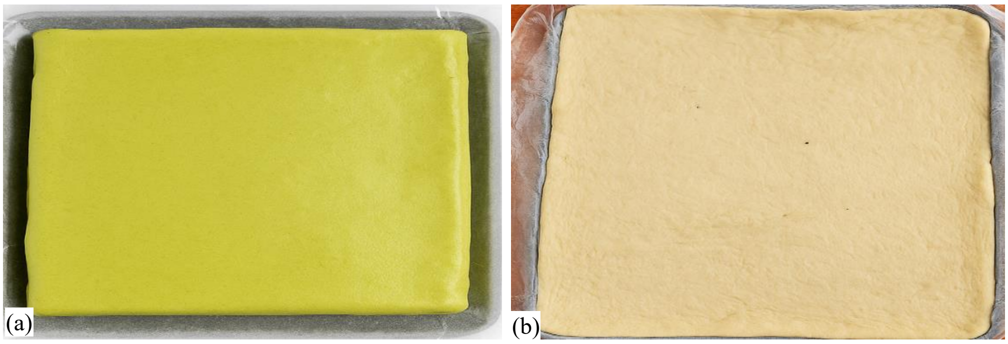
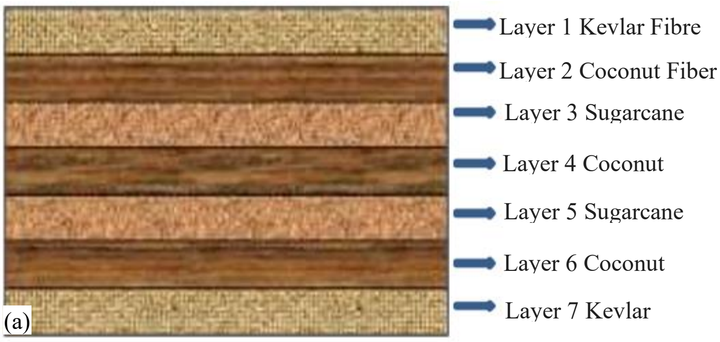


Figure 5. Sample preparation of dimension 200 × 310 mm for the thickness of 100 mm.

Table 3: Hand lay-up of composite molding process layer wise.

First layer, Kevlar fiber is put on mould having epoxy resin and hardener	
Second Layer, Coconut Fiber is Arranged On Kevlar Fiber and Resin, Hardener is Applied.	
Third layer sugarcane bagasse is arranged on coconut fiber and resin, hardener is applied on it	
Fourth layer coconut fiber is arranged on sugarcane bagasse and resin, hardener is applied on it	
Fifth layer Kevlar fiber is kept on coconut fiber and resin, hardener is applied.	



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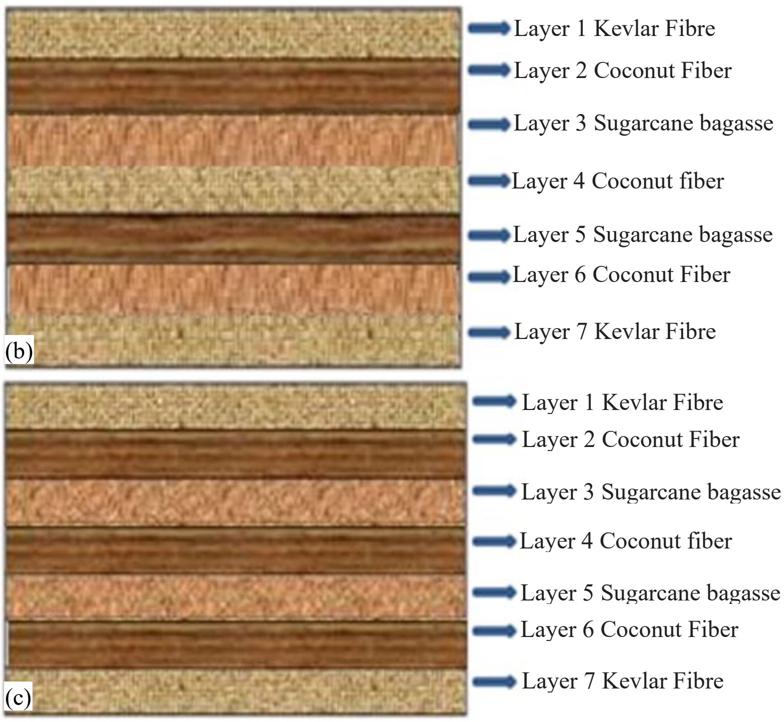

Figure 6. Layer wise fibre arrangements of (a) Sample 1, (b) Sample 2 and (c) Sample 3

Figure 7. Tensile strength measurement using universal testing equipment.

EXPERIMENTATION AND TESTING

UTM made Tensile Test

When applied to the material in compliance with established norms, an axial pull is produced, and the outcomes are measured using precise scientific techniques. Tensile testing is one of the most common mechanical tests done on materials. The experimental test setup of Tensile testing in UTM machine is systematically revealed in Figure 7.

By determining the force required to stretch a specimen to its breaking point, design engineers may determine material properties that help them predict how materials and products will behave in their intended applications. The evolution of products is greatly influenced by the quality of the materials used in manufacture. Figure 8 depicts that the values of ultimate tensile strength which can be observed maximum as 107.215 N/mm for the sample 3. It is due to the more blended layer of each fibre elements with various thicknesses. The observations of Tensile testing outcomes are listed in Table 4.

Wear Test

A method for assessing how surface activity may result in erosion or sideways displacement of material from its "derivative" and initial location on a solid surface is wear testing. This test is frequently employed as a straightforward way to assess the workability of materials in use. Because various materials respond differently in friction states, it could be required to do mechanical studies that replicate the circumstances the material would meet in practical usage. These materials are subjected to compressive stresses and forces during operation, and their dependability is determined by how well they can tolerate these loads and forces. Good manufacturing practices and efficient quality control begin with the ease of use of a wear testing machine for materials. Manufacturers must maintain quality control systems to ensure compliance with standards and consistent product quality that meets consumer expectations.

There is currently no easily available, reasonably priced, and efficient locally manufactured wear testing equipment in Egypt for metallurgy researchers. The foreign wear machines are beyond the researchers' means, costly, and hardly available. The necessity to create a multifunctional, effective wear machine with solely locally available materials and components led to the design and building of a wear testing machine. These will improve efficiency, quality control, and sound manufacturing practices in the construction material business while simultaneously fostering national economic growth. They will also be reasonably priced and freely available for surface study. Figure 9 illustrates the design and construction of pin-on disc wear test machines. Wear testing on pin-on discs is performed by rotating the disc at a constant speed while exerting a constant normal stress at the contact. The wear rate, which was lower in samples 1 and 3, is determined by continuously measuring and storing the weight loss. The study measured how different loads affected the wear rate by designing a setup to determine material removal for samples 1, 2, and 3, as shown in Figure 10. Table 5 lists the observations of the samples' wear test findings.

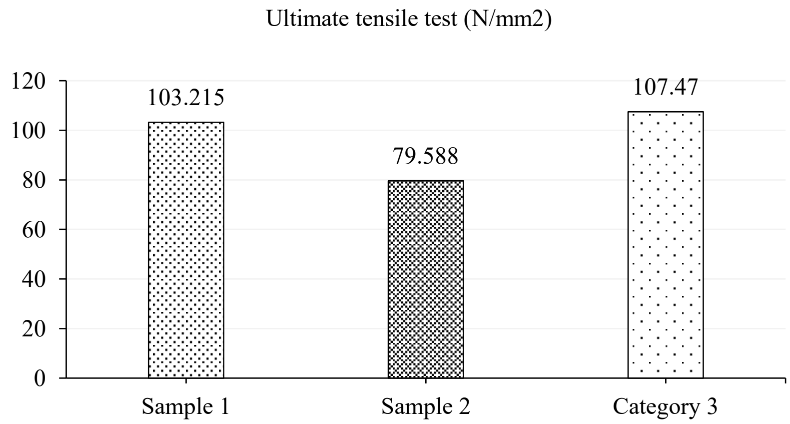

Figure 8. Ultimate tensile strength.

Table 4. Observations of tensile testing.

Samples	Ultimate tensile strength (N/mm)
Sample 1	103.215
Sample 2	79.588
Sample 3	107.47

Table 5. Observations of wear testing results of samples.

Samples	Before weight(Kg)	After weight(Kg)	Weight loss(Kg)
Sample1	4.5883	4.5879	0.0004
Sample2	5.4837	5.4821	0.0016
Sample3	5.3256	5.3250	0.0006

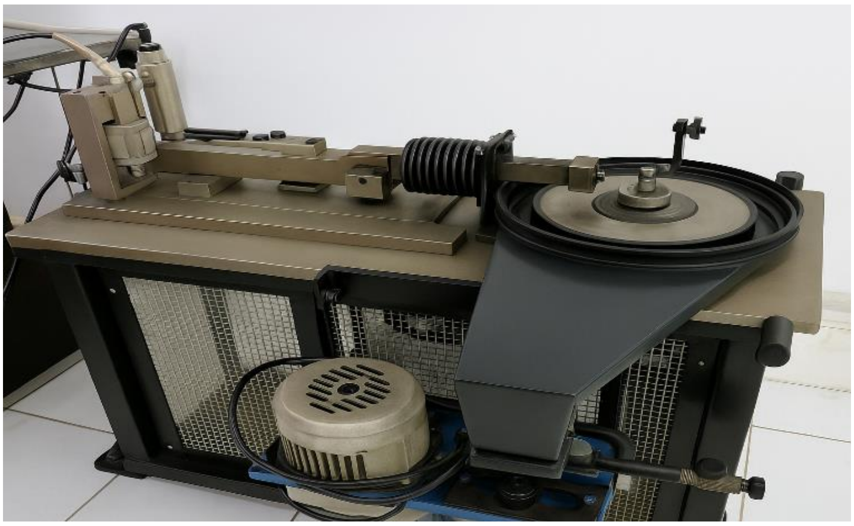

Figure 9. Wear test performed on pin-on-disc setup.

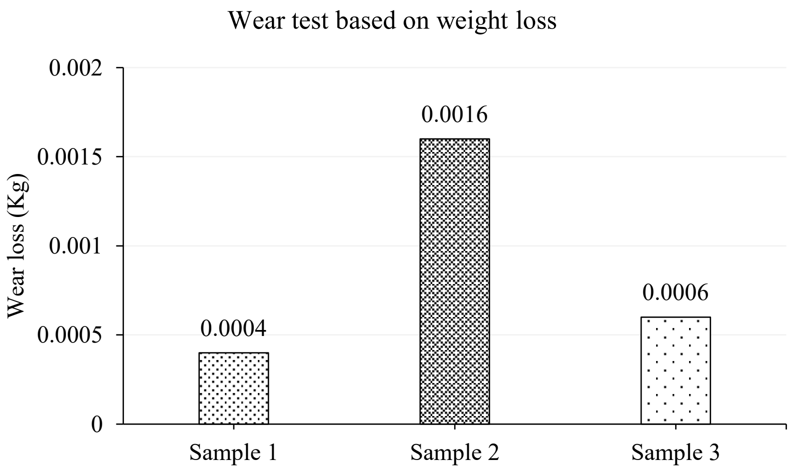

Figure 10. Wear test results of composite specimens.

UTM made Compression Test

Compression testing is one of the most fundamental types of mechanical testing, along with tensile and flexion tests. As illustrated in Figure 11, the comparison of ultimate stress values of the tested specimens, represented in kN/mm, clearly indicates the variation in tensile strength among the samples. And shown in Figure 12, compression and tensile testing are used to ascertain how a material will behave under functional crushing loads. A test specimen, usually of either a cuboidal or cylindrical shape, is subjected to compressive pressure using platens or specific fixtures on a universal testing machine. The characteristics that are established during the test and displayed as a stress-strain diagram include the elastic limit, proportional limit, yield point, yield strength, and, for some materials, compressive strength. Compression testing allows manufacturers to assess the safety and integrity of components, materials, and final products at various points in the production process. Potential applications include evaluating the strength of an automotive windshield and determining how long concrete beams used in construction will last. As indicated in Table 6, materials by means of high tensile strength typically (though not always) have low compressive strength. Similarly, materials with high compressive strength typically exhibit low tensile strength. Because of this, compression testing is commonly used on brittle materials such as concrete, metals, polymers, ceramics, composites, and corrugated materials like cardboard. These materials are commonly used in load-bearing applications where their ability to remain intact under compression loads is crucial.

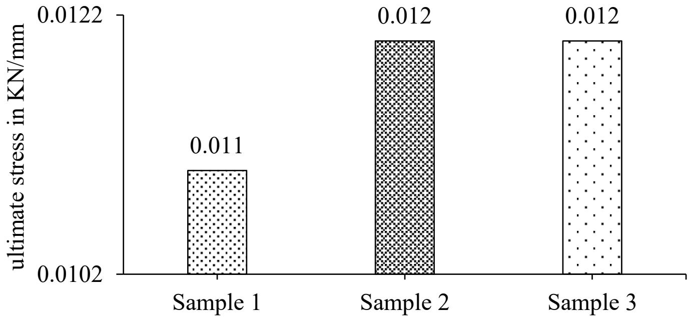

Figure 11. Comparison of ultimate stress values of specimens represented in KN/mm.

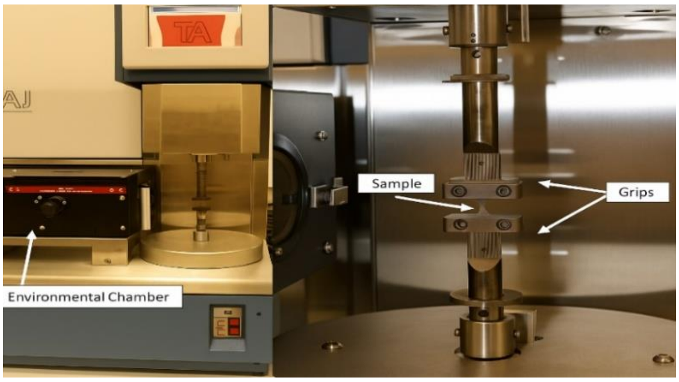

Figure 12. Compression and tensile testing arrangements.

Table 6. Ultimate stress values of each samples.

Sample	Ultimate Stress (KN/mm)
Sample1	0.011
Sample2	0.012
Sample3	0.012

Table 7. Displacement occurred teach Sample for the corresponding loads.

Load (kN)	Displacement of Sample-1(mm)	Displacement of Sample-2(mm)	Displacement of Sample -3(mm)
0.3	0.38	0.208	0.325
0.6	0.6	0.4	0.75
0.9	0.818	0.599	0.808
1.2	0.994	0.79	1
1.5	1.068	0.915	1.148
1.8	1	1.024	1.188

Double End Shear Test

The universal testing machine is used to perform the double - end shear test. After preparing the specimen for an appropriate cross-section and fixing it in a fixture, the shear force is delivered until all three samples have been sheared entirely. As seen in Figure 13, the load versus deflection curve is produced, and the peak load value represents the shear strength. The double end shear test was taken in the ASTMD7167-M11standard.The test specimen length 200 mm, 20 mm in width, and 4 mm in the thickness. The test results shown in figures. The total no of sample 3 sample was taken. The maximum shear load was obtained as 1.2 kN. The maximum displacement was 2.7 mm, and the maximum load can be obtained once it gets shear failure. The failure occurred due to shear stress, which led to the disruption of the fiber orientation. The displacement that occurred at each sample for the corresponding loads is listed in Table 7.

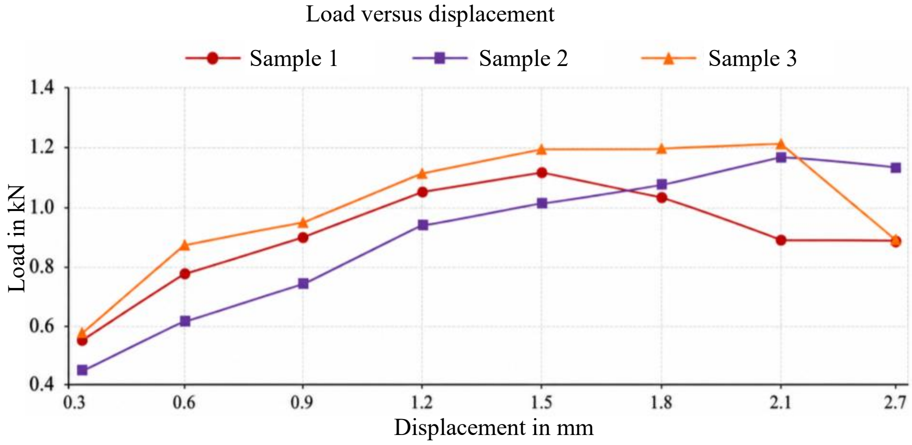

Figure 13. Displacement levels of sample 1, sample 2 and sample 3.

RESULTS AND DISCUSSION

Dynamic Mechanical Analysis

Dynamic Mechanical Analysis (DMA) is a thermo-mechanical technique used to measure the viscoelastic behavior of polymeric and composite materials under periodic stress. It provides information about the storage modulus (elastic response), loss modulus (viscous response), and damping factor (tan δ), which are essential for understanding energy dissipation and stiffness over a range of temperatures and frequencies.

One technique for characterizing and researching materials is dynamic mechanical analysis. When researching the viscoelastic behavior of polymers, it is very helpful. The complex modulus may be found by applying a sinusoidal load and tracking the strain on the material. This method may be used to find the glass transition temperature of a material and to detect transitions that correlate to different molecular movements. The temperature of the sample or the stress frequencies are often changed to change the complex modulus. Long molecular chain polymers have special viscoelastic properties that combine the qualities of Newtonian fluids with elastic solids. The mechanical characteristics of elastic materials are described by the classical theory of elasticity, which holds that stress and strain in minute deformations are proportionate. This kind of stress response is independent of strain rate. The classical theory of hydrodynamics describes viscous fluids by relating stress response to the rate of strain.

The MSE cost center includes the TA User Log for the DMA. This log must be filled out, and it is recommended to complete it before starting any measurement to ensure the information is not missed or forgotten. On the desktop, there is an Excel file called "The Log." The program should launch automatically when a user logs in for the first time. Please be aware of the following before you begin: Before beginning, read over this technique. Make sure that the cylinders have the right pressure and that the correct gas lines are connected. On your desktop, complete the DMA log spreadsheet. Figure 14 represents the DMA result for vibration into temperature analysis.

Activate the refrigerator. Turn the breaker switch on the chiller first, then switch it to "on," and then push the start button. After completing this step, please refrain from starting any measurements yet. Prepare a sample of most measures are covered by ASTM standards; hence, it is highly advised that users refer to the relevant standard in order to learn more about particular sample preparation for the DMA. For the sake of this process, it will be presumed that the 3 -point bend test using a 15 mm span was successful. The thickness of samples might range from 1 mm to 5 mm. According to ASTM standard E1640-04, the ratios can be 1:5:20 or 1:10:50, using 15 mm as the default fixture. Once your sample has been loaded (for a 3 -point bend), lower the ASTM standard E1640-04 states that the ratios can be 1:5:20 or 1:10:50, with 15 mm as the default fixture. If the furnace hasn't already been reduced, do so after adding your sample (for a 3 -point bend), then cover the top.

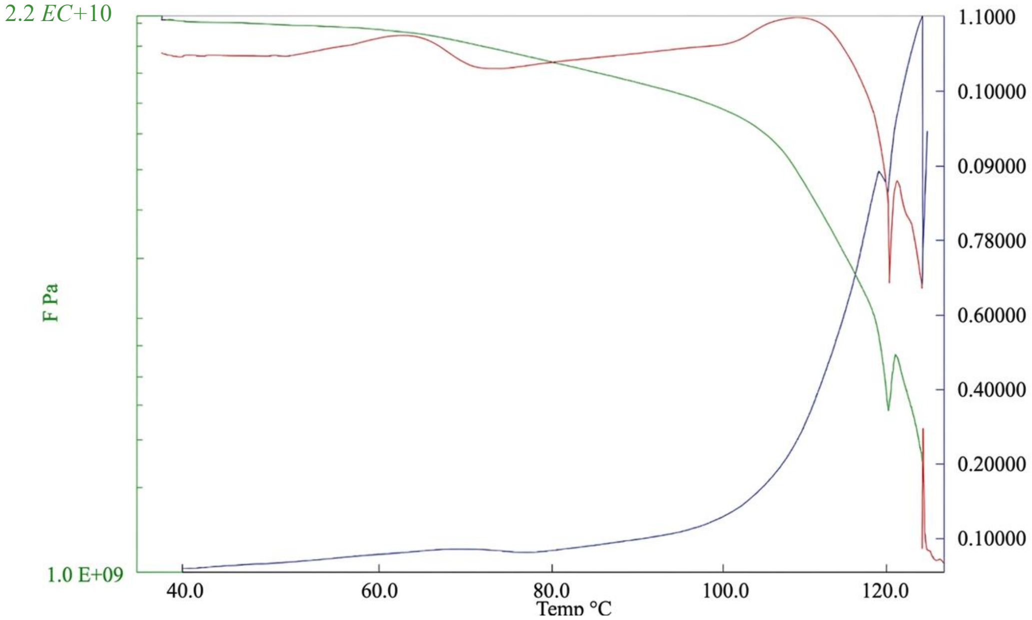

Figure 14. DMA Results for vibration to temperature analysis.

Install the appropriate fixture as instructed if it is necessary for your measurement. If not, the probe will need to be changed. The probe should rest on the area in the center. As taught, adjust the probe. The prepared sample should be spread out throughout the area. This point will serve as the zero height. Carefully lower the probe until it just touches the top surface of the sample, ensuring proper contact without applying extra pressure. Lift the furnace and remove the covering. Example: Cover the furnace's mouth with the collar. Select DMA by pressing the button just once while the three apps are visible at the top of the screen. The "method editor" and "instrument viewer" dialogues will both appear. Double-click "Pyris Manager" on the desktop to launch the program. A column of icons on the right side of the screen allows direct control of the DMA. Open the method editor for the specific measurement, if one has been prepared. To ensure that the sample may be removed for subsequent users, take note of how long the scan will take. The instrument viewer is the second dialogue that appears on the screen. The system updates the force, frequency, amplitude, temperature, and time in real time, and the Instrument Viewer continuously refreshes once the scan begins. The data analysis graph is the third dialog that appears after the scan is finished. Choose the data analysis window, then choose File, then Export Data, and finally choose ASCII to save the data as a.txt file. A dialog will open; check the box next to incorporate data points.

Importance of Scanning Electron Microscope Outcomes

Scanning electron microscopes (SEMs) have become powerful and versatile instruments for material characterization, particularly in the past several inordinate lengths of time, as the size of materials used in many applications has continued to shrink. Electron microscopes employ electrons for imaging, just the way light microscopes use visible light. SEMs create images using electrons reflected or ejected from the sample's surface, while transmission electron microscopes (TEMs) form images by detecting electrons that pass through an ultra-thin specimen. Since electrons have a wavelength that is significantly shorter than light's, SEMs can see objects with greater detail than light microscopes.

Figures 15, 16 and 17 explained the wear and fracture surface of SEM images. Figure 15 was shown in the wear surface of the SEM Images. The wear surface was shown in the adhesive fracture of the SEM images. The worn-out sample SEM images were shown in Figure 15. And Figure 16 was shown in tensile fracture SEM images. The tensile fracture was shown in the enlargement of fibers. The fibers shown in the ductile fracture surface of SEM and Figure 17 were shown in the flexural test specimen. The specimen was shown the voids. The voids were shown due to hexo-thermal heat generation formed.

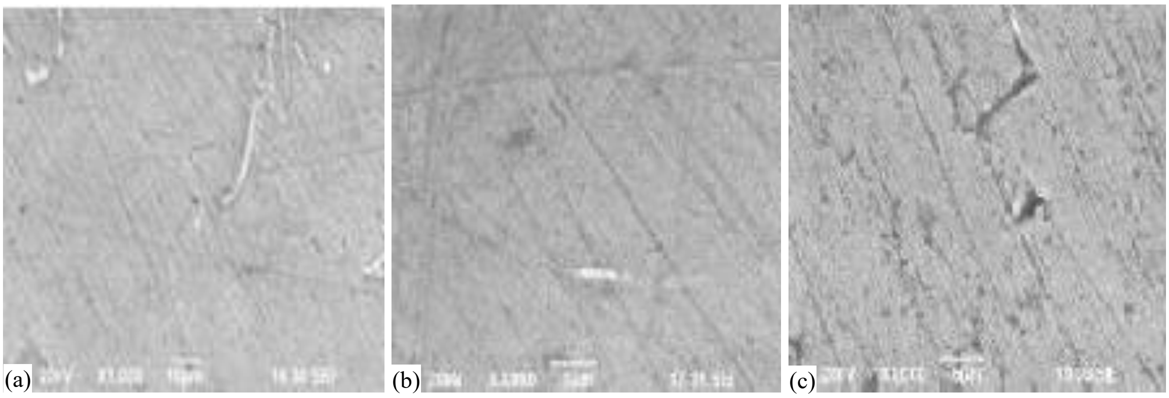

Figure 15. SEM microstructure of wear tested specimen 1.

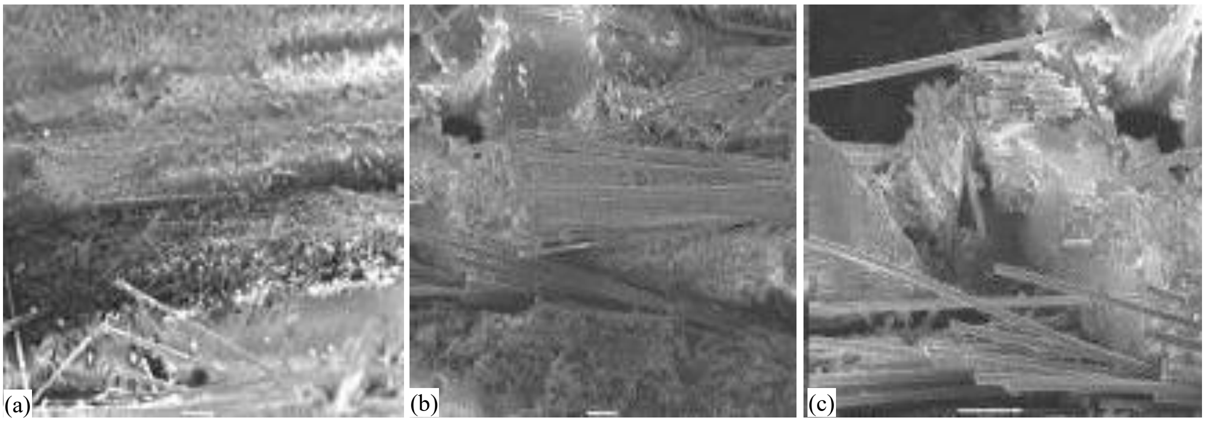

Figure 16. SEM image of tensile fractured specimen 2.

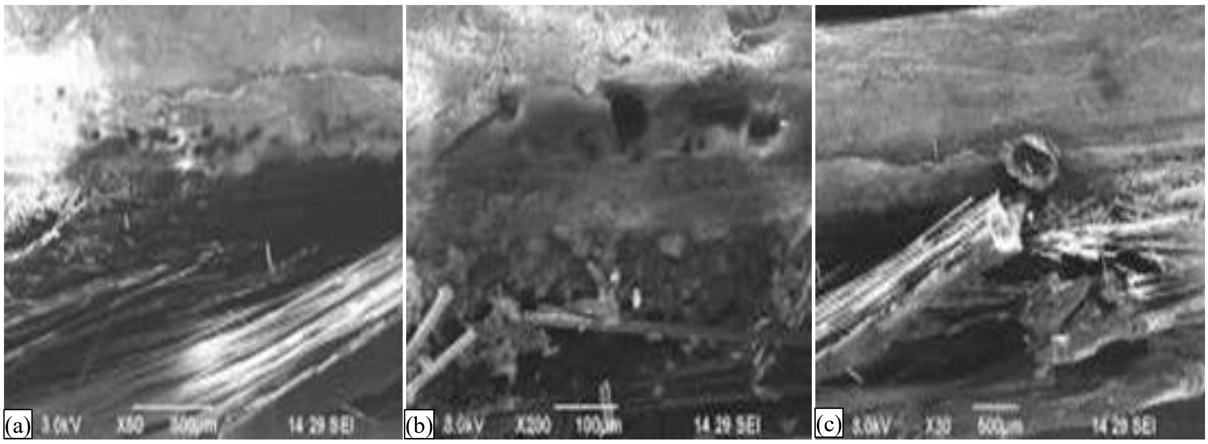

Figure 17. SEM microstructure of flexural tested specimen 3.

Statement of Novelty

A powerful specimen with outstanding mechanical qualities of brake pads used for automotive applications may be constructed from five layers of fiber composite made from uneven ratios of Sugarcane Bagasse, Coconut Fiber, and Kevlar Fiber. Each composite in this brake pad uses advanced material reinforcements and layer patterns to prevent failures caused by friction and shear. This section highlights the overall creativity and innovation demonstrated throughout the research work. Also, the brake pad's design allows for the evaluation of the link between mechanical testing and finite element analysis for the full computation of deformation and stress levels.

CONCLUSIONS

The tensile strength of the composite material increased with an increase in fiber content. The maximum tensile strength obtained was 107.479 KN/mm^2. The addition of Kevlar fiber makes the components even have an even stronger structure. The wear strength has increased, which was identified through the less amount of wear that has occurred. According to SEM studies, the compacted cellulose structure of the coconut fiber and bagasse may have improved the composite material's qualities. The fibers following the alkali treatment grew finer because the hemicellulose dissolved, improving the fiber–matrix adhesion, according to SEM micrographs of the fracture surface of the NaOH-treated fiber composites. The composite material can be used in making brake pads instead of using asbestos, which is harmful to the environment and human beings.

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Author Contributions

1. V. Pugazhenthi* – Conceptualization, Experimental Investigation, Data Analysis, and Manuscript Preparation.
2. P. Ashok Kumar – Methodology Development and Material Characterization.
3. R. Rajappan – Supervision, Review, and Validation of Results.
4. S. Vandaarkuzhali – Data Collection and Literature Review.
5. P. Gurusamy – Fabrication and Testing Support.
6. K. R. Rekha – Statistical Analysis and Visualization.
7. N. Ramanan – Experimental Assistance and Draft Editing.
8. B. Somasundaram – Proofreading and Technical Review.

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