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Research Article

Mechanical Properties of Banyan Fiber-Reinforced Sawdust Nanofiller Particulate Hybrid Polymer Composite

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The utilization of renewable raw materials, such as natural fiber composites, can be prioritized in the building industry as it transitions to a bioeconomy. The sustainable product can improve environmental protection; therefore, the present work is stated with the natural fibers of chopped banyan fiber reinforced with sawdust nanocellulose epoxy-based composite fabricated by hand layup process. To identify the mechanical effects of tensile strength, flexural strength, impact strength, and hardness value for five different weight ratios of chopped banyan fibers and sawdust nanofiller materials, the composite weight ratio was made with 60% of matrix phase that was fixed for all five samples and 40% of reinforcement phase in which the fibers and filler percentage can vary for five samples. The results are revealed sample E (50 g of banyan, 25 g of saw dust, 110 g of epoxy, and 185 g of laminate) given a more tensile strength of 39 MPa and a flexural strength of 34 MPa, and sample A was given a high impact energy absorption capacity of 18 Joule compared with other samples of hybrid composite; and also, the SEM morphological was used to identify the surface interaction and failure mode of this composite laminates.

1. Introduction

The trend of the fibers, the material's behavior of composites can be for example semi-isotropic, anisotropic, or orthotropic [1]. The fibers in the composites might be synthetic or natural fibers. Synthetic fibers are man-made and comprise thousands of fibers having a width of somewhere in the range of 5 and 15 micrometers. Since such little sizes are hard to deal with, the useful type of conventional fiber is a strand, which is created by combining countless fibers into a group [2]. The materials such as fiber-reinforced polymers (FRP) are lightweight materials that help in calculating the material by ordering the fibers in a specific direction to enable the mechanical behavior of the component in a direction, and it also has high firmness [3]. Composites are denoted as the mixture of ceramics and fiber-reinforced polymer in the structure of mixed material [4]. Sandwich constructions with several cores may offer more structural strength than single-core sandwich structures [5]. The dynamic properties of the multiple-core sandwich construction were required due to its importance. Various examinations have been directed on a few kinds of fibers, for example, kenaf, hemp, flax, bamboo, feathers, and jute to consider the impact of these filaments on the composite materials in mechanical properties [6]. The natural fiber-strengthened hybrid polymer has been utilized to supplant the synthetic composites. However, the whole supplanting of things to come with hybrid composites is adequately low because of its colossal contrast in properties when contrasted with manufactured filaments. For improving the properties of the composite, the filaments can be treated with different synthetic concoctions and matrix mixes. FRP composite has been utilized in numerous territories as aviation, vehicle, and construction [7]. The fusion of at least two filaments into a solitary polymer lattice drives the advancement of hybrid composite. Hybridization can improve the mechanical properties of single fiber-strengthened polymer composite. It demonstrated that the mechanical properties of regular fiber strengthened polymer composite increment because of consolidation of similarly high-extension fibers [8]. The composite materials were manufactured by utilizing banana fiber, glass fiber, epoxy resin, and valuation of mechanical conduct of created composite materials. From the outcomes, it was seen that the most extreme elasticity 19 MPa was acquired in 15 mm fiber length and 20% fiber loading. The most extreme flexural quality 32.5 MPa was gotten in 10 mm fiber length and 15% fiber loading. The most extreme effect quality 2 J was acquired in 15 mm fiber length and 20% fiber stacking. The greatest hardness quality 23.6 hardness values were acquired in 10 mm fiber length and 15% fiber loading. It was presumed that better mechanical practices were found in the composite example of 10 mm fiber length and 15% fiber loading, respectively [9, 10]. A developed composite was made by banyan/ramie fibers, and the evaluated mechanical properties show that banyan fiber loading can improve the structural properties; the chemical bonding between the epoxy matrix banyan fibers is significant with 5% more than the ramie fiber loading composite laminates [11]. The filler materials are used to improve the mechanical properties along with fiber reinforcement. Sawdust filler loading can increase of 35 MPa tensile strength compared to that without filler material laminates that is 4% higher tensile strength through this sawdust cellulose filler material [12]. The addition of ceramic particle reinforcement of natural fiber composite was increased during the thermal analysis of hybrid composites [13]. Thermosetting polymer usage quit increasing when fabrication of natural fibers was reinforced due to the significant bonding capacity of an epoxy matrix with fiber reinforcement for fabrication of composite laminates [14]. Growing global environmental concerns, as well as new environmental restrictions, have prompted the development of new environmentally friendly recyclable composites. To be widely employed in the furniture, automotive, or construction industries, the recyclable composite must meet the minimum mechanical qualities [15]. Based on the above pieces of literature, this work deals with the fabrication of hybrid composite by using chopped banyan fiber, and sawdust cellulose is reinforced with epoxy polymer matrix through the hand layup process, quantifying the effect of hybrid composite by evaluation of mechanical properties and surface morphology of hybrid composite.

2. Materials and Experimental Process

Materials used for this research work are banyan fiber extracted by wetting process from the banyan tree [16] and sawdust cellulose fillers extracted from wood [17] which is supplied by SM composites, Chennai, India. For enhanced bonding capabilities of natural fibers, the resin particle is a blend of Biphenyl-F type LY556 Epoxy polymer and Araldite HY 951 hardener [18] which is supplied by Javanthi enterprises, Chennai, India. The basic properties of materials are given in Table 1.

Ficus benghalensis is the scientific name for the banyan fiber employed in this study, which is commonly found in the Indian Subcontinent [19]. To improve the mechanical properties of the hybrid composites, sawdust with an average size of 150 microns is employed as a filler ingredient. The hand layup fabrication technique is used to fabricate this banyan fiber composite laminates, and the wooden mold box was prepared with the dimension of 30 cm × 30 cm and cleaned thoroughly at an initial stage [20]. As a mold release agent, laminate sheets coated in liquid wax were placed inside the mold. Then, the first layer of chopped banyan fibreon on top of the mold and the predetermined epoxy resin with a hardener ratio of 10 : 1 was mixed [21]. An electric stirrer can increase the capacity of the modified epoxy matrix's mixing capacity. It can also be filled with sawdust. Then, the second layer of chopped banyan fibre was applied to the mold box. The same process was applied for all the other samples. Five different versions of the filler materials—sawdust cellulose and chopped banyan fiber—-were used to measure the impact of the hybrid composite, followed by the epoxy matrix, which was the same for all five samples. The filler materials were 70/5, 65/10, 60/15, 55/20, and 50/25 grams. The same procedure was repeated for all other samples using various mold boxes, and after the fabrication, laminates were placed in a hot furnace for 3 hours at a heating rate of 5°C/min. Additionally, for better curing of these materials, bricks weighing 5 kg were compressed on top of the laminates for 24 hours before being removed to conduct the additional testing [22]. The weight ratio of chopped banyan fiber, sawdust filler, and epoxy matrix is given in Table 2. The fabricated composite laminate image is shown in Figure 1.

2.1. Testing of Hybrid Composite. Fabricated samples of five different weight fractions of chopped banyan fiber composite were conducted mechanical tests: tensile test, flexural test, and impact test as per ASTM standard. UTM (FIE UTN-40) is used to test the tensile strength of the hybrid composite, according to the ASTM procedure D638. The flexural strength of chopped banyan fiber composite was evaluated as per the ASTM 790 standard through 100 series modular three-point bend test (electromechanical tester) at 9 KN load that was applied on the specimen prepared by the standard. The Izod impact test is used to evaluate the impact resistance of hybrid composites, according to the ASTM procedure D256 [23]. The ASTM protocol indicated a sample size of 110 mm × 12.5 mm × 6 mm with a v-notch in the middle.

Table 1: Mechanical properties of banyan fiber, sawdust filler, and epoxy resin.

Properties	Banyan fiber	Sawdust	Epoxy resin
Young's modulus (GPa)	2.6	—	3.5
Tensile strength (MPa)	39.3	—	83
Density (g/cm^3)	1.52	1.69	1.15
Type	Chopped fiber	Particles	Clear liquid
Category	Natural fiber	Natural filler	Thermosetting polymer

Table 2: The weight ratio of banyan fiber-reinforced hybrid epoxy composite.

Sample	Weight of banyan fiber in (g)	Weight of sawdust filler in (g)	Weight of epoxy matrix in (g)	Weight of composite laminate in (g)
A	70	5	110	185
B	65	10	110	185
C	60	15	110	185
D	55	20	110	185
E	50	25	110	185

Figure 1: Fabricated banyan fiber hybrid composite laminates.

3. Results and Discussion

Reinforcements of chopped banyan fiber and sawdust cellulose filler blended with epoxy polymer matrix composite were fabricated, and mechanical tests are conducted; the results of each sample are varied due to different weight fractions of chopped banyan fiber and sawdust filler material.

3.1. Tensile Strength. The graph shows the tensile strength results of chopped fiber composite laminates in Figure 2; the results are revealed during the gradual tensile loading condition chopped banyan fiber that was given the superior tensile strength (Sample A) compared to sawdust filler loading of fabricated epoxy polymer composite. In the sample, a tensile strength of 39.15 MPa was given, and it is observed that the addition of 38% chopped banyan fiber into the fabrication of composite laminates can increase the overall laminate tensile strength of the hybrid composite. The least tensile strength was observed in sample E that shows 21.8 MPa due to the less weight fraction of chopped banyan fiber which can reduce the tensile strength of the hybrid composite. When adding 35% chopped banyan fiber into the composite material, it results in tensile strength of 35.15 MPa (sample B) which is 10% lesser than sample A, and similar results were observed in sample C that also revealed 30.2 MPa which is 20% lesser than sample A.

In another work, a developed composite made of sisal/jute fiber-reinforced epoxy composite shows the results in tensile strength that was increased with increasing the jute fiber layer into the composite laminates due to the better adhesion properties between jute fiber with epoxy polymer matrix compared to sisal fiber loading of hybrid composite [24]. Therefore, chopped banyan fiber can transfer during the gradual load on the composite compared to sawdust filler loading. It can reduce the stress concentration factor and increase mechanical stability and also reduce the failure rate of hybrid composite material. The chopped banyan fiber composites of all samples revealed the general material behavior of increasing stress and strains that are directly proportional up to their elastic limit of hybrid composite.

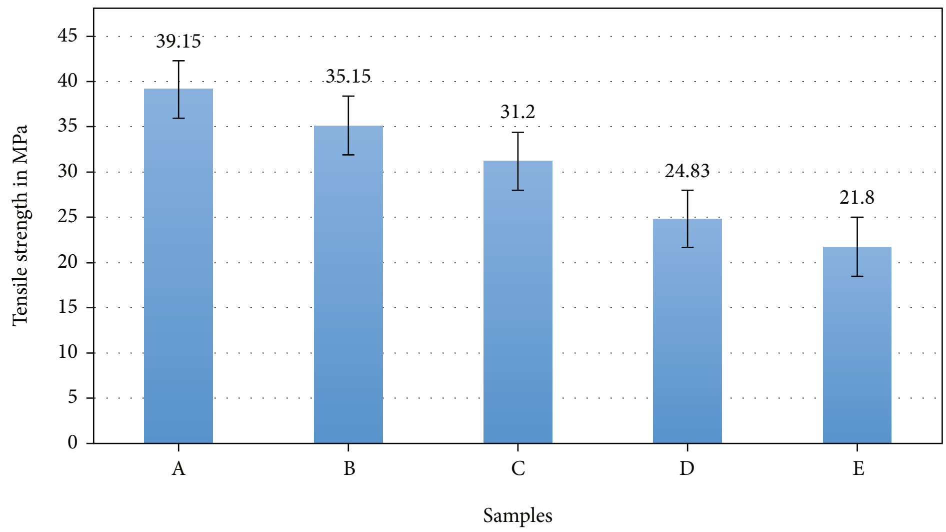

Figure 2: Tensile strength of banyan fiber composite.

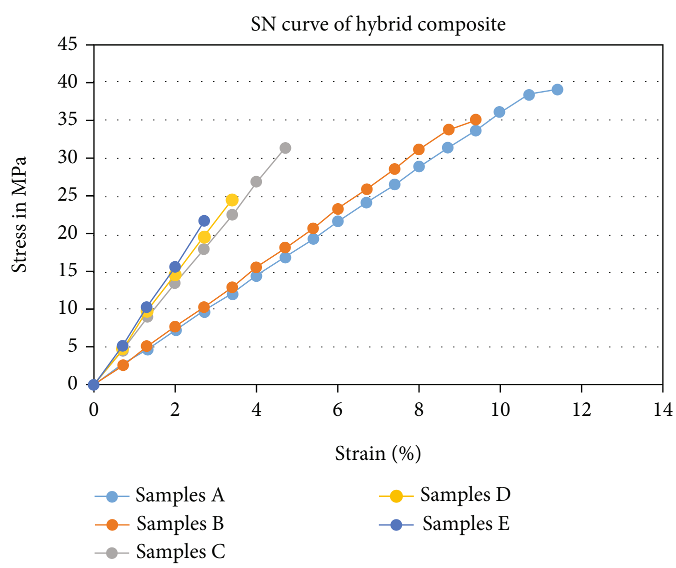

Figure 3: The stress vs. strain curve of banyan fiber composites.

The stress vs. strain curve of the hybrid composite during the tensile test is shown in Figure 3.

3.2. Flexural Strength. Investigational outcomes were observed in the flexural strength properties of the hybrid composite graph as shown in Figure 4; the maximum flexural strength was obtained due to increasing the weight fraction of chopped banyan fiber into the composite. The flexural strength of sample A is 34.37 MPa which is 11% more than sample B and 43% higher flexural strength compared to sample E of hybrid composite. The huge variation in flexural strength between samples A and E is due to the addition of chopped banyan fiber and sawdust filler loading for the fabrication of composite material, in sample A, which contains 38% chopped banyan fiber and 2% sawdust filler, and at the same time, sample E contains 27% of chopped banyan fiber and 13% sawdust filler materials; however, the epoxy matrix is constant of 60% in all the five samples of hybrid composite [25].

3.3. Impact Strength. The graphical results on impact energy of all five laminates are shown in Figure 5; sawdust particulates in all five samples for improvement of mechanical properties have been achieved because the observed results from this research work can be compared to other works without filler materials that can reduce significantly their mechanical strength. The impact of sawdust filler is to improve the flexural strength considerably due to the bonding behavior between the banyan fiber and sawdust filler materials being better with thermoset polymer. The natural reinforcement materials give significant results in sample A to E flexural strength values that are enough to make the composite materials for lightweight application, and in the sample, weight fraction is suitable to enhance the strength

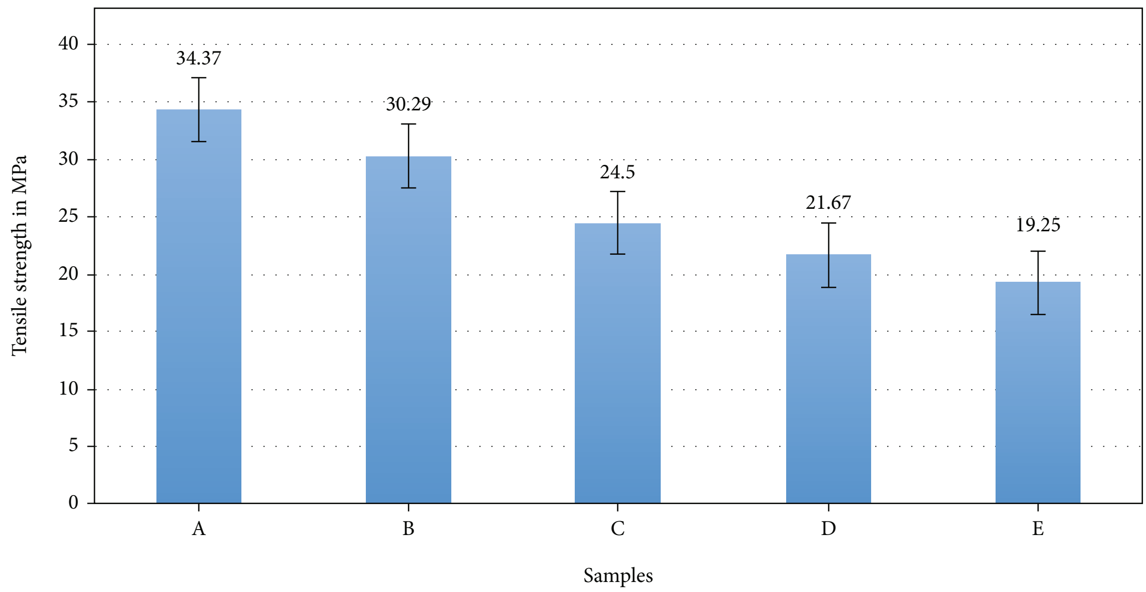

Figure 4: Flexural strength of banyan fiber composites.

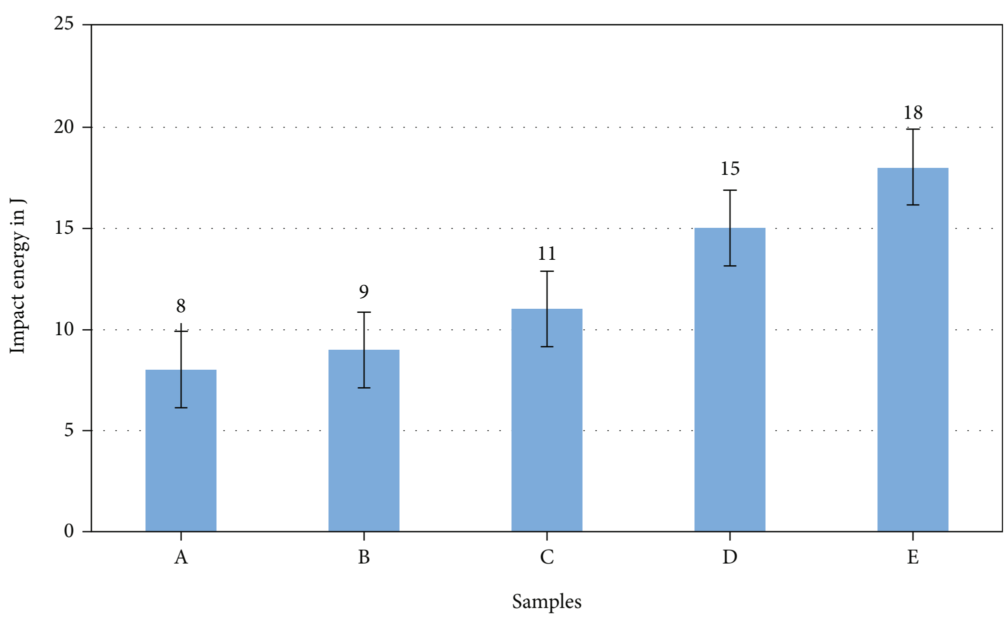

Figure 5: Izod impact energy absorption of banyan fiber composite.

during vibration analysis of hybrid composite. In another work, a developed composite made of banyan/neem fibers reinforced polymer composite, and the results revealed that the matrix element and the banyan fibers are both fragile and snap when a force is applied to them. Four layers of cross-ply banyan fibers could not provide adequate strength to withstand the impact force. It was discovered that the neem discontinuous fibers intertwined with one another. The resulting composite has isotropic behavior as a result of this. As a result, its impact resistance increased by 50%. The composite's impact strength was improved by increasing the number of layers of neem fiber reinforcement [26].

The banyan fiber composite was conducted to the Izod impact test for identifying the energy absorption during the sudden loading condition on the material and the capacity to withstand different types of applications. The maximum impact energy observed in sample E is 18 J which contains 50 g chopped banyan fibers, 25 g sawdust fillers, and 110 g epoxy matrix; the maximum result was obtained due to the variations in sample E have more amount of sawdust filler loading compared to other samples. Sample A with 8 J is the least impact energy among all the five samples of hybrid composites, and increasing sawdust filler loading can improve the impact energy absorption

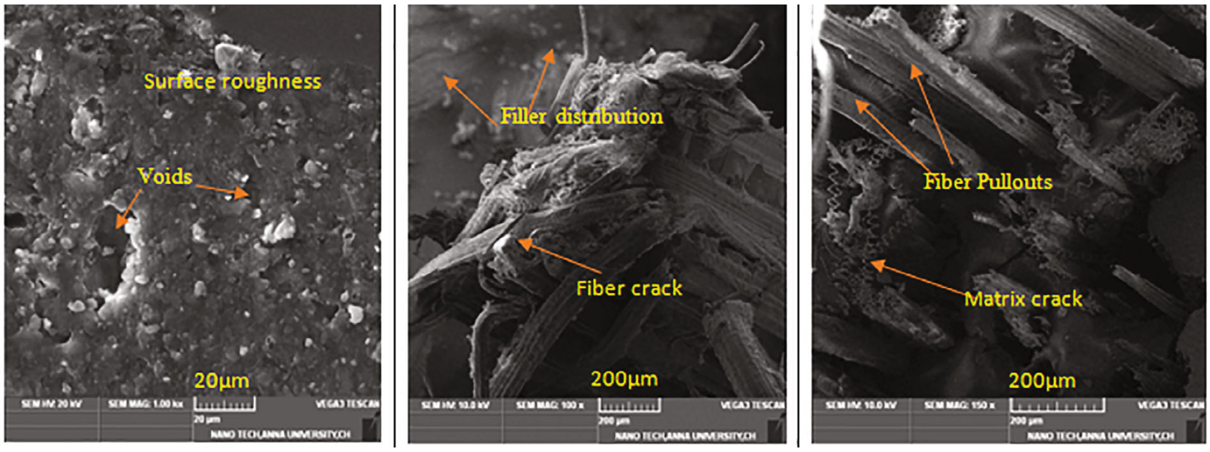

Figure 6: SEM image of banyan fiber composite.

compared to increasing chopped banyan fiber loading into the composites. Therefore, sawdust fillers are strongly bonded and reduce their stress concentration factor, which are used to resist the sudden force more compared to fiber loading of hybrid composite.

3.4. Morphological Analysis of Banyan Fiber Composite. The created hybrid composites microstructural characteristics are investigated in order to assess the specimen's deformation under loading conditions [27]. The microstructural characteristics of the material are observed using scanning electron microscopy in this research investigation. The fiber pullouts, cracks, and failure are the most common causes of hybrid fiber failure when subjected to tensile loading, as shown in the scanning electron micrographs. These failures are mostly caused by a poor interface between matrix orientations, resulting in stress concentration and severe breakdown of the hybrid composite material. The use of a higher weight percentage of chopped banyan fiber in the development of hybrid composites resulted in fewer matrix cracks due to a more uniform stress distribution. As the weight fraction of sawdust in hybrid composites increases, the amount of stress concentration in the material increases, resulting in a more complex level of cracks during the tensile loading of hybrid composites. The SEM image of banyan fiber composite is shown in Figure 6.

4. Conclusion

The composite materials were fabricated with chopped banyan fibers, sawdust fillers, and epoxy polymer matrix, the mechanical properties of tensile strength, flexural strength, and impact energy absorption were conducted, and also, surface characterization was analyzed by scanning electron microscopic analysis. The following points are the major findings of this research work:

(i) The combination of chopped banyan fiber, sawdust filler, and an epoxy matrix is suitable to fabricate the composite materials, and the bonding capacity of these materials is enough to enhance the material strength for lightweight applications

(ii) Tensile strength of banyan fiber-reinforced hybrid composite for sample A is 39.15 MPa which is the maximum when compared to other samples, and the least tensile strength is 21.8 MPa in sample E, when increasing chopped banyan fiber loading that can withstand more tensile loading compared to increase of sawdust filler loading of hybrid composite

(iii) Flexural strength results are also similar to tensile strength; however, the maximum flexural strength of the hybrid composite is 34.37 MPa in sample A, and the average of 29% more flexural strength was observed during the three-point bend test of hybrid composite

(iv) Impact energy absorption of banyan fiber composite is maximum when increasing sawdust filler materials due to the bonding capacity between the materials used in this research and can resist the more sudden load of hybrid composite

(v) Based on the SEM test results, the major failure was observed due to the fiber cracks, fiber pullouts, and voids present in the composite laminates, and to reduce the failure, the fiber pretreatment process can improve the mechanical strength of hybrid composites

(vi) Future work may concentrate with parameter analysis by various multiobjective techniques

Data Availability

The data used to support the findings of this study are included within the article. Further data or information is available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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