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Research Article

Experimental Investigation on Density and Volume Fraction of Void, and Mechanical Characteristics of Areca Nut Leaf Sheath Fiber-Reinforced Polymer Composites

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Natural fiber-reinforced polymer composite is a rapidly growing topic of research due to the simplicity of obtaining composites that is biodegradable and environmentally friendly. The resulting composites have mechanical properties comparable to synthetic fiber-reinforced composites. In this regard, the present work is formulated with the objectives related to the development, characterization, and optimization of the wt% of reinforcements and the process parameters. The novelty of this work is related to the identification and standardization of the appropriate wt% of reinforcements and parameters for the processing of the areca nut leaf sheath fiber-based polymer composites for enhanced performance attributes. With this basic purview and scope, the composites are synthesized using the hand layup process, and the composite samples of various fiber compositions (20%, 30%, 40%, and 50%) are fabricated. The mechanical characteristics of biodegradable polymer composites reinforced with areca nut leaf sheath fibers are investigated in the present work, with a focus on the effect of fiber composition (tensile properties, flexural strength, and impact strength). The properties of composites are enhanced by combining the areca nut leaf sheath fiber and epoxy resin, with a fiber content of 50% being the optimal wt%. The Scanning electron microscopy (SEM) investigations also ascertain this by depicting the good interfacial adhesion between the areca nut leaf sheath fiber and the epoxy resin. The tensile strength of the composite specimen reinforced with 50% areca nut fiber increases to 44.6 MPa, while the young's modulus increases to 1900 MPa, flexural strength increases to 64.8 MPa, the flexural modulus increases to 37.9 GPa, and impact strength increases to 34.1 k J/m^2. As a result, the combination of areca nut leaf sheath fiber reinforced epoxy resin shows considerable potential as a renewable and biodegradable polymer composite. Furthermore, areca nut leaf sheath fiber-reinforced epoxy resin composites are likely to replace petroleum-based polymers in the future. The ecosustainability and biodegradability of the composite specimen alongside the improved mechanical characteristics serve as the major highlight of the present work, and can help the polymer composite industry to further augment the synthetic matrix and fiber-based composites with the natural fiber-reinforced composites.

1. Introduction

Natural fiber-reinforced composites have been the focus of continued research over the last decade due to their prospective to substitute synthetic fiber-reinforced plastics in a number of technical applications and industries at a lower cost with improved sustainability [1–2]. A variety of polymer matrix composites with a diversity of fiber reinforcements, such as carbon fiber, glass fiber, natural fibers, hybrid, and so on, were developed when a high strength-to-weight ratio was required in components that demanded great routine and effectiveness [3, 4]. When it comes to ecologically friendly materials and the need to develop a wide range of sustainable manufacturing and engineering components, the natural fiber composites play a critical role. Natural fibers, with their high mechanical properties and biodegradability, play an indisputable role as a reinforcement material, and they are readily available around the world [5, 6].

Many varieties of natural fibers, such as coir, banana, pineapple, areca, and bamboo, have a crucial place in several areas of investigations attributed majorly to the price efficiency and strength characteristics. Electrically resistant, thermally insulating, and corrosion resistant, natural fiber-reinforced composites have been of great importance in automotive, aerospace, marine, and structural domains [7, 8]. The tensile modulus of natural polymer composites increases as the volume fraction of the fiber increases, this is also ascertained by the findings on the influence of the volume fraction of the reinforcements on the composite specimens [9, 10]. The longer the fiber length, the higher the composite's strength according to a study of the tensile characteristics of an areca fiber composite. Given that the chemical treatment of fibers alters mechanical properties, researchers discovered that the treatment of the areca nut fiber increases mechanical strength when compared to untreated fibers [11, 12]. The curing duration for a composite is also crucial in determining its maximal strength potential. Other mechanical properties of the areca fiber composite were examined, taking into account, the effect of volume fraction, post-curing time, and different treatment conditions for successful bonding [13, 14]. When compared to untreated fibers, alkali-treated fibers exhibit a significant improvement in flexural strength [15, 16].

Impact strength improved with postcurative treatments, while alkali-treated composites became brittle as curing time increased, thus the optimized curing of the composites with alkali is important for sustainable improvement in the properties [17, 18]. The mechanical properties of areca nut leaf sheath fiber as well as their usage as a reinforcement in polymer composites are an important area of research [19–24]. The fibers are obtained by water retting the areca nut sheath. The areca nut fruits are protected by the sheath, which are intertwined with the leaves [21, 22]. These areca sheaths are initially surface treated to eliminate pollutants and other particles, subsequently followed by water retting and post-treatment [23–24]. The treated areca nut sheath has excellent mechanical properties. Hence, the fibers from these sheaths can be efficiently used to reinforce the epoxy polymers and obtain the composite. This also suffices the need of global manufacturers [23–24]. Since manufacturers all around the world are being pressed to think about their products' environmental impact, and environmental awareness is increasing as a result of strict legislations [25–34]. As a result, natural fibers are becoming more popular as a reinforcement for polymer-based composites, owing to their renewable nature. Polypropylene is a cost-effective thermoplastic with unique physical, chemical, mechanical, thermal, and electrical properties [35–40]. It has inferior impact strength but higher heat resistance characteristics and tensile strength than the high- or low-density polyester. *Areca catechu* trees, which generate massive leaf sheaths, can be found along the east and west coast of India and other mid-tropical nations [41–48]. This otherwise useless item can be utilized to make composite materials. Each year, the plastics sector uses several billion pounds of fillers and reinforcements. With enhanced compounding technology and novel coupling agents that allow for higher filler/reinforcement content, the utilization of these natural fibers in polymers is projected to increase [49–54]. The sustainable manufacturing of the eco-compatible products may become more widespread in the future, perhaps reducing the need for petroleum-based polymers significantly [55–58]. If a considerable portion of the fillers were acquired from a renewable undeveloped resource, it would be very helpful, both in conditions of biodegradability and in terms of socioeconomic benefits, of course, the most environmentally friendly material would be an agro or bio-based renewable polymer reinforced with agro-based fibers [59, 60]. Several researchers have accomplished research on the thermomechanical characteristics of the natural fiber-reinforced polymer composites, and have reported that these composites exhibit better performance attributes at optimized fiber loading [61–64].

With the review of the literature on natural fiber-reinforced polymer composites, it is herewith evident that there is a sufficient research gap in the domain of the synthesis and mechanical characterization, viz., the density, tensile, impact, and flexural properties of the areca nut fiber-reinforced epoxy composites for a multitude of applications. Especially, the optimization of the areca nut fiber weight percentage in the matrix for enhanced strength and performance attributes is a novel approach toward the standardization of the fabrication procedures for automotive parts, viz., bumper beams, bumpers, battery casings, hoods, car roofs, etc. Thus, the present work is framed with the objectives involving the synthesis of the composite laminates by hand layup techniques and their characterization for density, volume fraction of voids, tensile, flexural, and impact characteristics, for the utilization of the composites in real-time.

2. Materials and Methods

ER 2074 Epoxy resin and the hardener were procured from SS Impex, Bengaluru, and the processed areca nut leaf sheath were procured from Tanvish P Agro Products Pvt Ltd. Bindiganavile. The areca nut leaf sheath was pretreated with acetone for deriving fibers for appropriate and homogenous

(a) (b) (c)

Figure 1: (a) Areca nut leaf, (b) sliced areca nut leaf sheath, and (c) chopped and sieved areca nut leaf sheath.

adherence. Areca nut leaf sheath fibers were made by drenching the leaf sheath for 22 days in water. The drenched fibers were then peeled from the resinous resources, washed, and air dried correctly. With the use of hand scissors, the areca nut leaf sheath fibers were cut into little pieces and sieved. After sieving, fibers of average lengths in the range of 5 to 6 mm were obtained. The fibers were then washed with distilled water and exposed to sunshine for around 48 hours. Prior to the manufacture of the composites, the fibers were dried out in a vacuum oven for 12 hours at 100°C [39–41].

Areca nut leaf sheath fiber and epoxy are used to make a composite material in this study. In this study, the areca nut leaf sheath fiber was treated with water to improve wettability. These water-treated areca nut leaf sheath fibers were then sun-dried and subsequently used as reinforcing materials in an epoxy resin matrix. The density and volume fraction of void, impact strength, flexural, and tensile characteristics of areca nut natural fiber composites were investigated in the present study. The highest impact strength, flexural strength, and tensile strength of areca nut leaf matrix composites were discovered for composite specimens fabricated with 50 wt% of fiber loading synthesized using the hand layup method. Figure 1 shows the polymer composites of (a) areca nut leaf, (b) sliced areca nut leaf sheath, and (c) chopped and sieved areca nut leaf sheath.

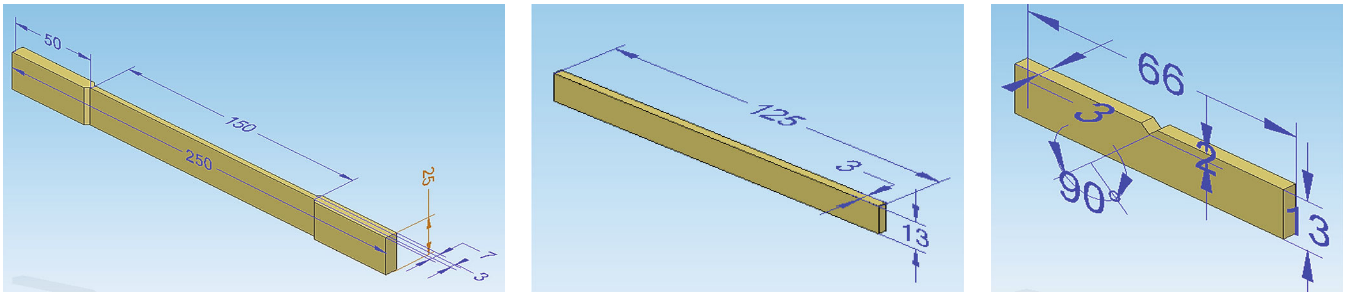
The mechanical properties of areca nut leaf sheath fiber were investigated, and it was discovered that the fiber has good mechanical properties, as demonstrated by various mechanical experiments, allowing it to be used in a diversity of applications such as the construction industry, automobile industry, marine components, aerospace parts, etc. It was also discovered that polyester/areca nut leaf composites do better than neat epoxy polymer in stipulations of mechanical properties.

2.1. Sourcing of Areca Nut Leaf Sheath Fiber. In this research work, the hand layup technique was used to synthesize the composites. As a releasing agent, wax was used to clean the mold ($150 \times 150 \times 3\,mm^3$). The combination of dried areca nut leaf sheath fiber and 3 : 1 ratio of ER 2074 Epoxy resin/hardener mixture was made and poured into the mold designed according to the ASTM standards. After pouring the mixture into the mold, an OHP sheet coated with wax was placed on the top layer of the mold and then rolled using a wooden roller of 25 mm diameter. This rolling operation on the top layer of the epoxy-fiber mixture is carried out to compact the mixture and remove any trapped air and voids from the composite. The rolled composite in the metallic mold is then cured at room temperature for 24 hours to facilitate the crosslinking of the polymers, which significantly improves the bonding between the fiber and the matrix and enhances the strength of the composites significantly. The fiber weight fractions varied from 20 wt% to 50 wt% in increments of 10 wt%). Table 1 gives the areca nut leaf sheath fiber chemical composition.

Table 1: Areca nut leaf sheath fiber chemical composition [55, 56].

Name	Percentage (%)
Hemicellulose	7.40
α-cellulose	66.08
Lignin	19.59
Pectic matters	19.59
Fatty and waxy matters	19.59

2.2. Characterization of the Composites for Density and Void Fraction. The mechanical and physical properties of the composites are significantly reduced by the presence of void content in the composites. Any of its mechanical properties can be greatly influenced by the void material of a composite. Higher void contents typically indicate lower resistance to fatigue, greater susceptibility to water penetration and weathering, and increased strength property variance or dispersion. To estimate the quality of composites, knowledge of the void content is desirable. In terms of weight fraction, the theoretical density of composite materials can be derived



(a) (b) (c)

FIGURE 2: (a) 3D model of a tensile test specimen as per the ASTM D638 standards. (b) 3D model of the Flexural test specimen as per the ASTM D790 standards. (c) 3D model of the Charpy impact test specimen as per the ASTM D256 standards.

from equation (1). The water immersion technique was used to determine the actual density (ρ_{act}) of the composite.

$$\rho_{th} = f_{fibre} \times \rho_{fibre} + f_{resin} \times \rho_{resin} + f_{hardener} \times \rho_{hardener}, \quad (1)$$

where f = weight fraction, ρ = density.

The suffixes m and f stand for the matrix and fiber of the composite materials, respectively. The technique of water immersion has been used to experimentally determine the actual density of the composites prepared. In composites, the volume fraction of voids is given by the relation in equation (2).

$$\text{Volume Fraction of Voids (Vv)} = \frac{\rho_{th} - \rho_{ac}}{\rho_{th}}. \quad (2)$$

In assessing the quality of composite materials, fiber and void volume fractions are essential parameters, while accurate fiber and void volume fraction assessments are based on fiber density information, as represented in the ASTM D2734.

2.3. Mechanical Characterization of Composite Materials. Mechanical testing is carried out on specimens according to the ASTM standards. The tensile and flexural tests are carried out on Asian Test Instruments to make ATEUTM20T model UTM. The composites are fabricated according to the ASTM D638 sample definition. The sample is found to have a gauge length of 150 mm, the total length of 250 mm, width of 25 mm, a thickness of 3 mm at the gauge length portion, and 7 mm at the gripping region. The sample is inserted into a UTM with a computer interface for information acquisition at a stable crosshead speed of 3 mm/min in anticipation that the specimen fails. The experiments are carried out in a 27°C chamber with normal atmospheric conditions.

The flexural test specimens are cut as per the ASTM D790 standards by the water jet machining process. The length of the flexural specimen is 125 mm, while the width of the specimen is 13 mm and the thickness of the specimen is 3 mm. Figure 2(b) depicts the 3D model of the flexural test specimen.

The Charpy impact test specimen used in the present work is machined in accordance with the ASTM D256 standards. The 3D model of the Charpy impact test specimen is depicted in Figure 2(c). The length of the specimen is 66 mm, while the width of the specimen is 13 mm and the thickness of the specimen is 3 mm. A "V notch" of 2 mm depth is cut at the center of the length of the Charpy specimen for providing the impact blow and characterizing the specimen for the impact strength.

The composite specimens with different wt% of the reinforcements are tested for the tensile, flexural, and impact characteristics and the results are tabulated and analyzed.

TABLE 2: Density and volume fraction of void.

Wt% of Areca nut	Resin wt%	Hardener wt%	Theoretical density (g/cm^3)	Actual density (g/cm^3)	Volume fraction of voids
20	60	20	1.694	1.612	4.841
30	52.5	17.5	1.580	1.499	5.112
40	45	15	1.466	1.401	4.388
50	37.5	12.5	1.351	1.301	3.700

3. Results and Discussion

3.1. Density and Volume Fraction of Void. In many applications, polymer composites are found to primarily substitute traditional metals and materials for their limited densities. The composite density depends on the relative percentage of the matrix and the reinforcing materials. Because of the presence of voids and pores, there is often a disparity between the measured and theoretical density values of composites.

The mechanical properties and even the efficiency of composites are considerably affected by these voids. Higher void content typically indicates lower resistance to fatigue, higher susceptibility to penetration and weathering under the influence of moisture content. Awareness of void content is desirable for the consistency of the composites to be estimated. The theoretical and calculated densities of composites of the areca nut fiber epoxy resin composite, along with the corresponding volume fraction of voids, are presented in Table 2.

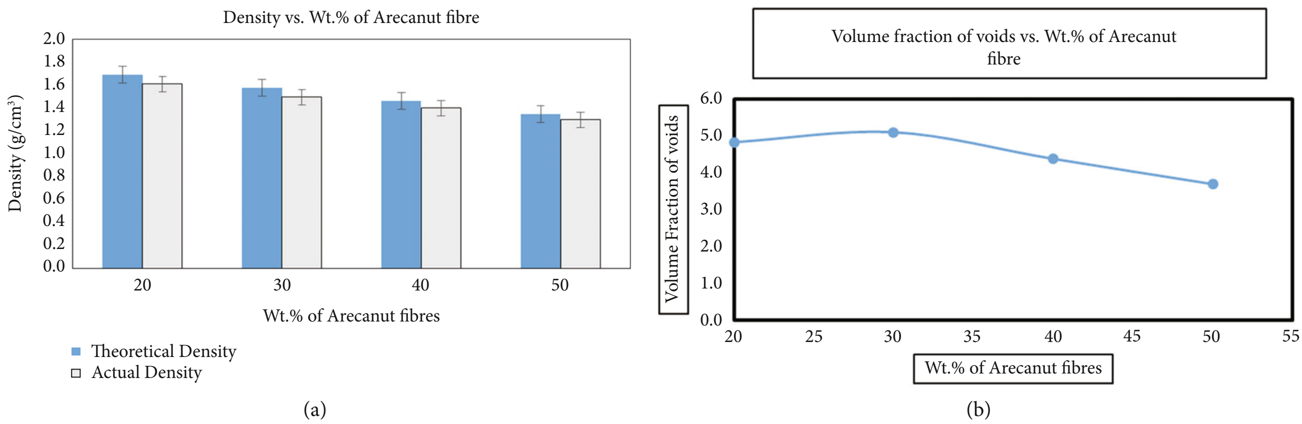


Figure 3: (a) Density vs. wt% of areca nut fibers. (b) Volume fraction of voids vs. wt% of areca nut fibers.

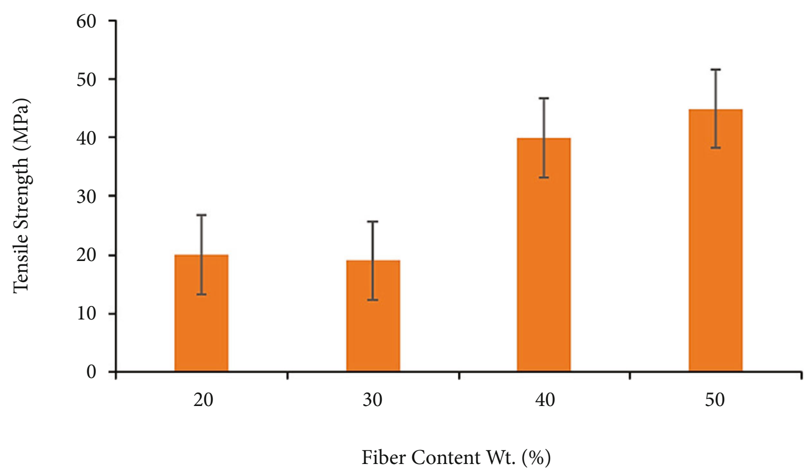


Figure 4: Tensile strength vs. fiber content.

It has been observed from the graph of density versus wt% of areca nut fiber in Figure 3(a), which the theoretical density decreases with the increase in the fiber wt% in the matrix. The theoretical density decreases from 1.694 to 1.351 g/cm^3 for the wt% of areca nut fiber content increasing from 20 to 50 wt%, respectively. The theoretical density for the different compositions of the composites is calculated from equation (1). With the increase in the wt% of areca nut, the density decreases. This is majorly attributed to the fact that the areca nut fiber is a low density, high strength natural fiber with a density of 0.78 g/cm^3 that decreases the mass and density for the given composite. The experimental density values for the composite also decrease with the increase in the areca nut fiber wt%. However, from the graph of volume fraction of voids vs. wt% of areca nut fiber in Figure 3(b), the volume fraction of voids initially increases with the increase in the composition of areca nut fiber up to 30 wt%, attributed to the entrapment of gases during hand layup and decreases with the increase in the areca nut fiber content, owing to the strong bonding and vacuum sealing followed for the subsequent hand layup processes for 40 and 50 wt% of areca nut fibers.

The density and volume fraction of voids have an impact on the mechanical properties of the composites, and this has been ascertained from the studies of Mehdikhani et al., who have reviewed the formation of voids and their effect on the characteristics of the composites. The increase in the volume fraction of the voids has a detrimental effect on the properties of the composites [65, 71, 72].

3.2. Tensile Test. The tensile test is an important material test employed to characterize the composite materials for its tensile characteristics, viz., the tensile strength and the tensile modulus. The tensile test coupons are fixed in the grippers of the UTM and slowly pulled by the shackles on either side of the specimen at a constant strain rate of 0.01/s. The tensile load is applied incrementally until the composite specimen fractures, and finally, the tensile strength and tensile modulus are computed in the system interface of UTM considering the ultimate tensile load, area, and strain of the composite specimens. Figure 4 shows the variation of the tensile strength of epoxy resin composite samples for varying areca nut fiber weight percentages. The tensile strength of epoxy resin increases as the proportion of fiber increases.

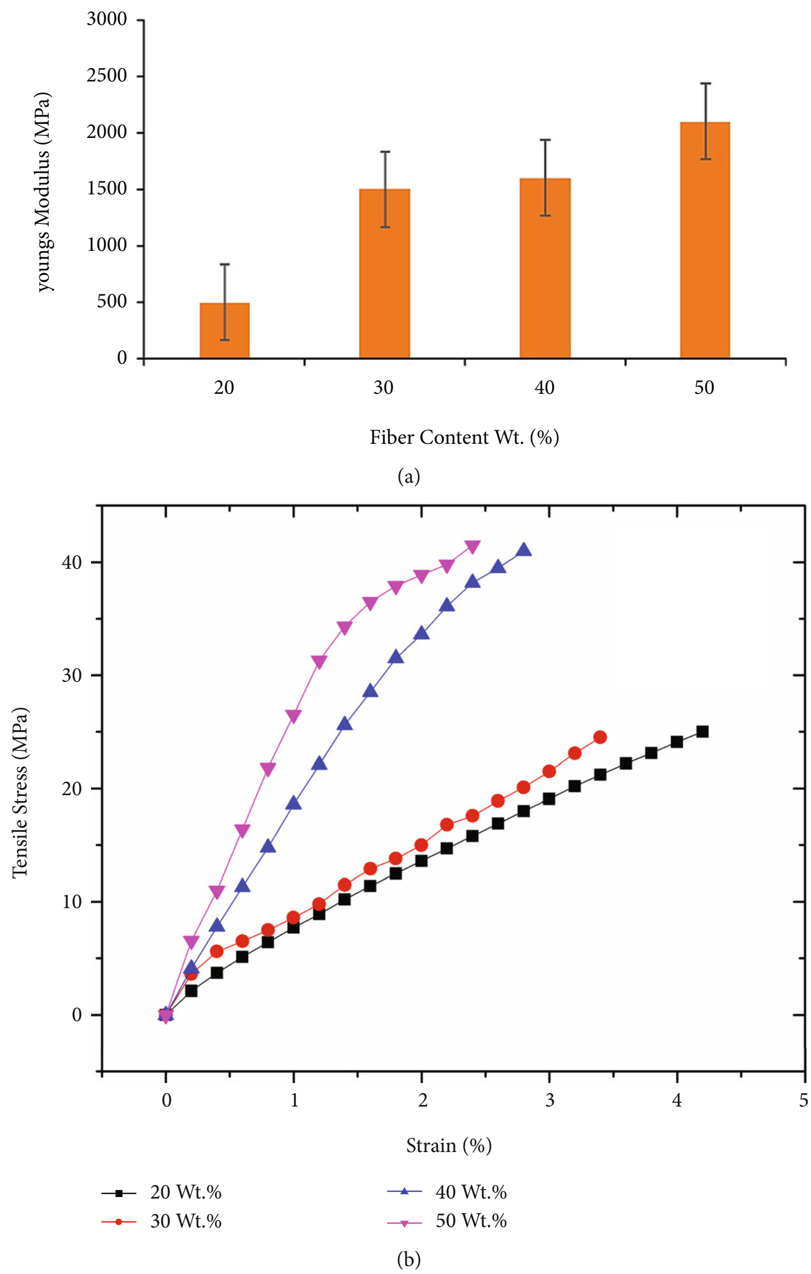


Figure 5: (a) Youngs modulus vs. fiber content. (b) Stress (tensile) vs. strain graph for different wt% of areca nut fiber.

The composite with 50 wt% areca nut fiber has the highest tensile strength of 42 MPa. When the fiber weight fraction decreases, the bonding weakens. Fiber content less than 30 wt% causes uneven fiber orientation, lowering the tensile strength of composite specimens. The tensile strength of composites is impacted by the fiber weight fraction as depicted in the graph. When the necessary fiber wt% is reached, the composite specimens' mechanical strength increases once more. As a result, we may estimate that the crucial weight percentage of the composites is around 50 wt%.

The modulus of elasticity of the specimen is depicted in Figure 5(a). Samples with 50 wt% areca nut fiber have the maximum modulus of elasticity of 1887.5 MPa, while samples with 20 wt% areca nut fiber have the lowest modulus of elasticity of 495.7 MPa. The modulus of elasticity increases with the increase in the wt% of areca nut fibers. These findings reveal that the ultimate tensile strength (UTS) and Young's modulus (YM) increase with the increase in the wt of areca nut fiber, due to the greater load-bearing capacity of the areca nut fibers and the transfer of the load from the epoxy matrix to the areca nut fibers. This is also evident from the stress versus strain graph for the different wt% of fiber reinforcement is shown in Figure 5(b).

The findings of Shubhakanta Nayak have validated the results of the present work, especially the use of the natural

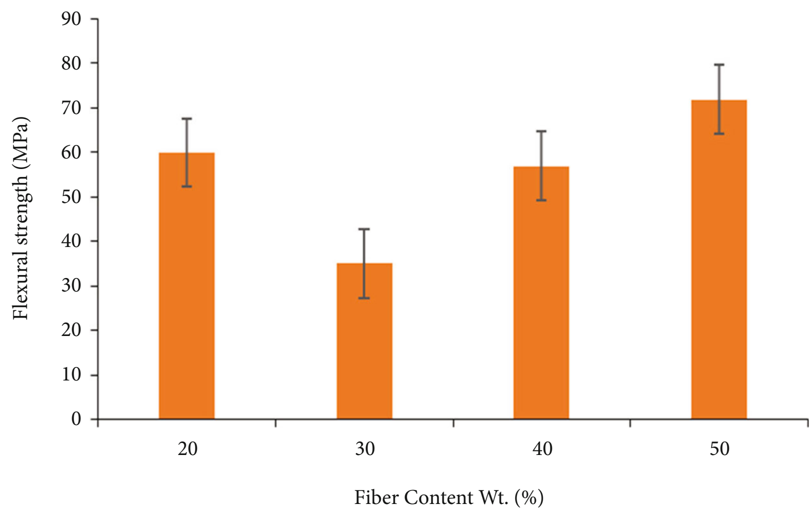


Figure 6: Flexural strength vs. fiber content.

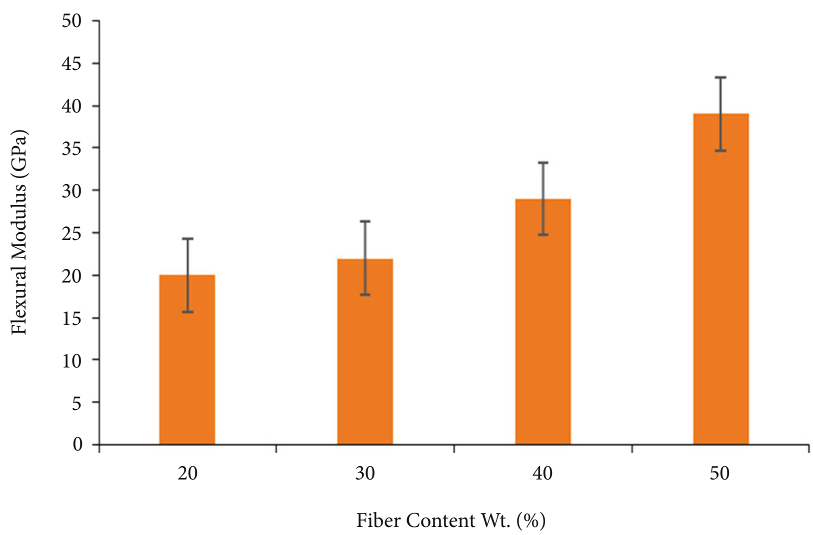


Figure 7: Flexural Modulus vs. fiber content.

fiber reinforcements in the composites is observed to enhance the mechanical characteristics up to a certain limit, provided the use of filler content is optimized in the matrix phase, with appropriate posttreatment [66].

3.3. Flexural Test. The flexural strength and flexural modulus of the composites subjected to flexural load for different wt% of areca nut sheath fiber are shown in Figures 6 and 7, respectively. The ER 2074 Epoxy resin/hardener mixture that serves as the matrix material has a flexural strength of 30.8 MPa and a modulus of 2.1 GPa, whereas the flexural strength of 20 wt% areca nut fiber-reinforced epoxy composite increased to 60.1 MPa, while the flexural strength for 30 wt% areca nut fiber-reinforced epoxy composite reduced to 32.9 MPa, However, with further increase in the wt% of areca nut fiber to 40 wt% and 50 wt%, the flexural strength increased to 59.66 and 73.2 MPa, respectively. The flexural modulus of the composites increased from 19.8 GPa for 20 wt% of areca nut fiber to 36.2 GPa for 50 wt% areca nut fiber (Figure 7). The flexural strength and modulus of the composite were found to increase progressively when the fiber content was increased. The composite with a 50 wt% fiber content yields the greatest performance. During flexural testing, the composite material is subjected to a variety of stresses at different depths. The inside of the bend (concave) and outside of the bend (convex) faces of the composite encounter compressive and tensile stress at the same time. The extreme layer of fiber determines the composite's flexural characteristics. The majority of composites fail under tensile stress before compressive stress. The fracture begins on the convex face of the beam and steadily spreads upward. This was also the case in the present work.

The findings of Santhosh et al. have presented the influence of the natural fibers on the fracture toughness and flexural strength characteristics of the composites. The use of natural fibers is found to enhance the flexural strength and

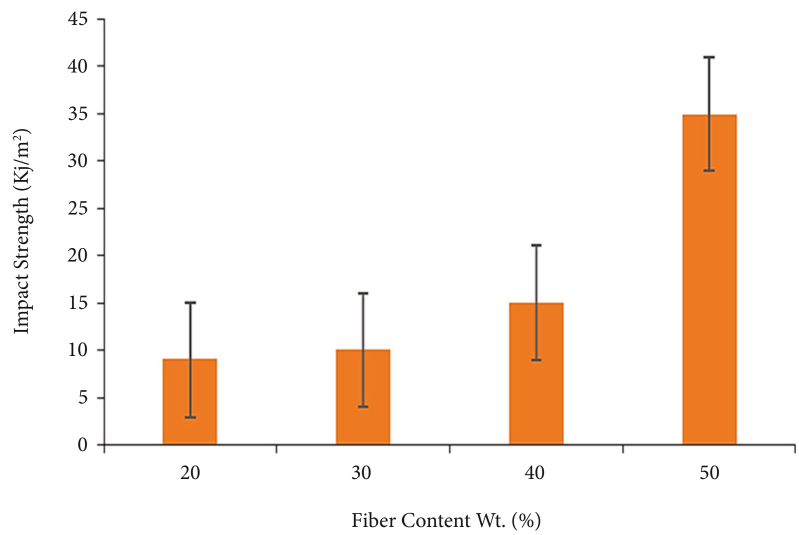


FIGURE 8: Impact strength vs. fiber content.

flexural modulus of the composites owing to the stronger bonding between the matrix and the reinforcement phase [67].

3.4. Impact Test. The impact test was carried out to evaluate the impact strength of the composite samples. Figure 8 depicts the impact strength of the composite samples. The composite with 50 wt% areca nut fiber has the maximum impact strength of 34.2 kJ/m^2, whereas the sample with 20 wt% areca nut fiber has the lowest value of 9.3 kJ/m^2. A variety of factors, including nonhomogeneous fiber distribution, can explain the variance in impact strength for composite specimens with varying wt% of fiber reinforcements. The composite's ability to absorb external forces is reduced due to nonhomogeneous distribution. However, the even distribution of the areca nut fiber reinforcements improves the impact strength of the composite specimens. The ability of the composite to absorb external stresses is improved when areca nut fiber reinforcements are coherently bonded with the matrix phase.

The reason for the increase in the impact strength of the composites with the fiber content is the microcoring and segregation of the fibers in the matrix, which will eventually bring about the enhancement in the impact strength of the composite, particularly attributed to the crosslinking of the polymers and the bonding between the epoxy resin-hardener mixture and fiber, which eventually creates a network that absorbs the impact loading. This is also ascertained by the findings of Shubhakanta Nayak, who have reiterated the significance of the strong bonding between the matrix and natural fiber reinforcements for enhancement of the mechanical characteristics of the natural fiber-based polymer composites [68, 69].

3.5. Morphological Test. The micrographic images of the fractured specimens were captured using a Hitachi Make SU 3500 Scanning Electron Microscope (SEM) at 100× magnification and a scanning voltage of 15 kV and a scan speed of 30 cycles/s. The SEM images of the tensile fractured surfaces clearly reveal the strong bonding between the matrix and the reinforcements. However, the development of linkages between matrix and polymer is inhibited by voids, which affects the mechanical characteristics of materials. The mechanical characteristics of composites are deteriorated as the number of voids increases. The tensile fractured surfaces of the composite specimens are shown in Figure 9. The advantage of the hand lay-up process is that the composite's strength and thickness may be regulated by increasing the thickness of the fibers and resins and thereby the voids can be reduced by carrying out the hand layup process in a controlled environment.

The morphological structure of the tensile fractured specimens of areca nut fiber-based composite samples for different weight fractions was studied from the fractographic images. The SEM images of the composite fiber surface morphology, cross-section, and tensile rupture zones for the wt % of the fibers varying from 20 to 50 wt% are shown in Figures 9(a)–9(d), respectively. The fracture morphology for 20 wt% of the reinforcements exhibits voids, matrix cracks,and fiber pullout (Figure 9(a)). However, with the increase in the weight fraction of areca nut fibers, the voids have drastically reduced. This is evident from the comparative evaluation of the SEM images in Figures 9(b), 9(c), and 9(d), respectively. The pits on the fiber surface indicate a rough and perforated surface. When utilized as a reinforcing material, the rough fiber surface aids to improve fiber-to-matrix physical bonding strength. From Figure 9(c), it is evident that the void formations are reduced to a greater extent, with the increase in the wt% of areca nut fiber reinforcements (40 wt%) and the fracture of the surface are majorly due to the matrix fiber debonding and fiber cracks, rather than the fiber pullout and delamination. Figure 9(d) depicts the fractured specimen of 50 wt% areca nut fiber-reinforced composite specimen. The cross-section of the fiber is found to be elliptical. There is a big visible lumen in the fiber's

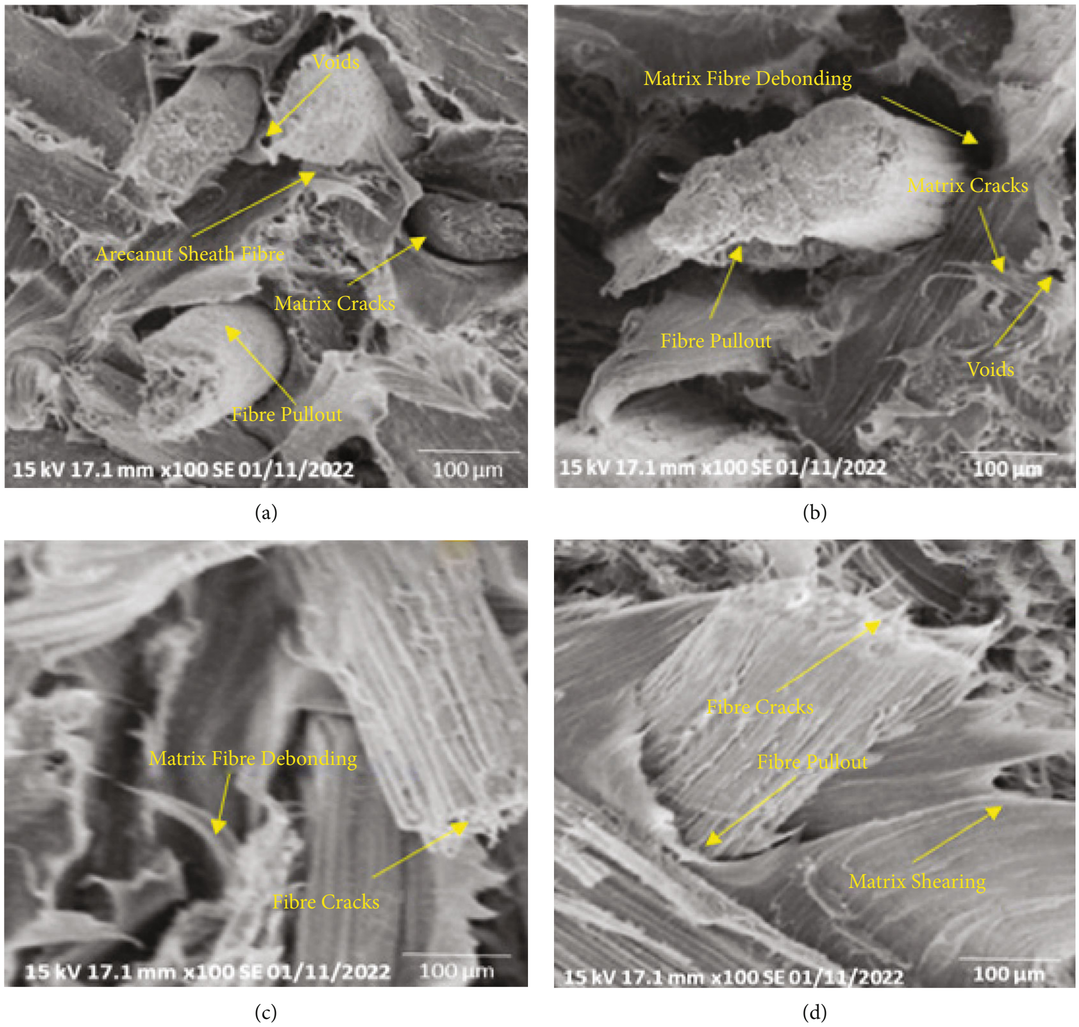


FIGURE 9: SEM images of fractured specimens for (a) 20% (b) 30% (c) 40%, and (d) 50wt% fraction.

center. Resin has infiltrated within the fiber network of the areca nut fiber employed as a reinforcing material, and it has completely encircled each and every fiber, and thus, the failure is more due to matrix shearing in the case of 50 wt% areca nut fiber-reinforced composite specimens, rather than the fiber cracks and ruptures.

Thus, from the fractographic analysis, it is herewith reported that the major causes of the failure of the composite specimens under tensile loading are fiber-matrix debonding, voids, and fiber pullout. However, with the increase in the wt% of the reinforcements, the damage of the composite specimens during fracture can be reduced and the failure of the composite specimens can be prolonged.

The SEM images also reveal the nature of fiber matrix bonding and the matrix shearing that occurs across the reaction planes of polymeric crosslinking. The stronger bonds are formed when the surface of the fibers is rough and facilitate the adhesion between the matrix and the fiber. When the bond between the matrix and the fiber is broken, a distinct pattern of fiber crack and matrix shearing is observed. The SEM analysis accomplished by Shubhakanta Nayak et al. has reported that the strong adhesion between the matrix and the reinforcements is observed to enhance the mechanical characteristics of the composites attributed to increased bonding strength that eventually withstand fracture of the composites due to different loadings and provide a framework model that eventually facilitates the composite laminates to sustain the shock loads [70].

4. Conclusion

The critical observation of the results and their subsequent inferences have provided an insight into the influence of the different wt% of areca nut fibers on the mechanical characteristics of the epoxy composites, and the conclusions drawn are as follows.

(i) The mechanical characteristics and morphological properties of the areca nut fiber-reinforced polymer composites are affected by the fiber content. Samples with 50 wt% fiber have the maximum tensile strength, modulus of elasticity, flexural strength, flexural modulus, and impact strength, while the samples with 20 wt% fiber have the minimum of properties.

(ii) The ultimate tensile strength for 50 wt% areca nut fiber-reinforced composite is 44.6 MPa, while Young's modulus is 1900 MPa, that is, the fiber weight fraction, ultimate tensile strength, and the modulus of elasticity satisfy the required criteria for their use in automotive dashboards, which is in the range of 1000–2500 MPa.

(iii) The flexural strength and flexural modulus are also important criteria for the use of the areca nut fiber-reinforced epoxy polymer composite in automotive applications, that is, the flexural strength for 50 wt. areca nut fiber-reinforced epoxy composite is 64.8 MPa, while the flexural modulus is 37.9 GPa.

(iv) The impact strength is also determined to be 34.1 k J/m^2, which is higher than the threshold value for the bumpers of the cars, thereby justifying the use of the areca nut fibers-reinforced composites in the automotive applications.

(v) The characteristics of the natural fiber-reinforced composites are affected by the sample's age. The decrease in the mechanical characteristics of the composites with the decrease in the weight percentage of the fibers is attributed to the existence of voids or cavities in the composite and is evident in the SEM images of the fractured surfaces.

(vi) Thus, the use of areca nut leaf fibers and control of the fabrication process in a vacuum environment can effectively reduce the void formation and increase the strength characteristics of the composites.

The results have also reported that the qualities of areca nut leaf fibers are equivalent to those of other natural lignocellulosic fibers such as coir, cornhusk, and banana fibers, and this fiber can be used as a low-cost reinforcing material in the creation of high-quality polymer matrix composites. The mechanical characteristics of areca nut leaf composites improve as the fiber loading of the composites increases. Also, the areca nut leaf fiber-based composite's mechanical characteristics reveal that it may be used as a construction material for automotive, marine, aerospace, and other important applications requiring high strength with less weight. The fibers of the areca nut leaf sheath are more fibrous than those of the other fibers, and this is evident from the SEM images. This is also an important attribute for the fabrication of the epoxy composites with improved bonding and strength characteristics, facilitating further research related to the applications of the composites in real-time with scope for mathematical and computational modeling of the fracture mechanisms and optimization studies for optimizing the process parameters, constituents of the matrix, and reinforcement for the fabrication of the areca nut fiber reinforced epoxy composite.

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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