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Fiber Orientation Effect on Mechanical Properties of Coconut Leaf Midrib Reinforced Polymer Composite

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ABSTRACT

This paper depicts the effect of fiber orientation on coconut midrib fiber reinforced composite material. For the experiment the collected midrib was used as reinforcing particle whereas mixture of epoxy resins and hardener performed the role of matrix. After fabrication two types of samples were prepared-0◦ specimen whose fibers were placed horizontally and 90◦ specimen whose fibers were placed vertically with ground. Flexural test, Impact Test and Rockwell hardness test were conducted on both types of specimen. Hardness showed no variation. But 0◦ specimen revealed almost 82% greater flexural strength and 59.67% higher impact strength than those of 90◦ specimen.

Keywords: Natural fiber reinforced composite, Coconut midrib fiber, Orientation of fiber, Mechanical performance

INTRODUCTION

From the pre historic ages, researchers and scientists have been continuously exploring newer and newer materials which may speed up the pace of the advancement of civilization. But in recent years environmental awareness has been added as a new criteria in this search. The natural fiber reinforced composite material is a revolutionary outcome of this search as natural fiber has tremendous advantages over synthetic fibers. Comparing to synthetic fiber, natural fibers offer low density, low cost, availability, renewability and recyclability, low processing expenditure, good mechanical properties, ease of collection and production which can make them a possible alternative to bio degradable and hazardous material [1-7]. There is a number of potential natural fiber like jute, bamboo, banana, pineapple, coconut, sisal, hemp, kenaf, rice, wheat etc. for which the researchers have conducted many experiments to discover their properties to be used as reinforcing particle [8]. However natural fibers incorporate some minus points too. Its hydrophilic nature and moisture absorbing quality cause poor binding with fiber and polymer. [8]. So scientists and researchers are undertaking many experiments to subside the limitations provided by natural fibers. There have been many investigations about jute, kenaf, hemp, bamboo, sugarcane, rice husk etc. but comparatively fewer on coconut midrib. Coconut midrib has a great opportunity to be used as a reinforcing material as it is very commonplace in tropical countries like India, Indonesia, Philippines, Brazil, and Sri Lanka etc. More than 90 countries produce coconuts totalling to 61.4 million tonnes per year [9]. Different parts of coconut tree have gained much attention of scientists. Coir is already an established and commercial fiber [10].

Different crucial properties of coir polymer composite such as dynamic characteristics, mechanical and morphological properties, and probabilistic tensile behaviour have already been investigated by a lot of experts [11-13]. Regarding coconut midrib fiber, Neeraj Dubey *et al* [14] investigated the tensile strength, tensile modulus, flexural strength, flexural modulus and Izod impact strength and found that coconut midrib enhanced the mechanical properties of pure polyester matrix to a huge extent. Mulinari *et al* [15] discovered that due to the treatment of alkali, fatigue life of coconut/polyester composite was decreased when applied greater tension. Sasikumar *et al* [16] experimented the tensile strength, flexural strength and impact strength with various volumetric percentage and concluded that mechanical properties decline with the rise of particle fraction weight. Again fiber of orientation is an important characteristic in analysing the mechanical properties of composite. An experimental investigation was conducted by Keshavamurthy *et al* [17] to study the influence of fiber orientation and it was found that glass/epoxy with 0◦ orientation yielded in higher strength than that of 30◦ and 45◦. The impact of fiber orientation on the PALF reinforced bisphenol composite was unleashed by Vinod *et al* [18]. Sandeep *et al* [19] reported that 0-90◦ glass/epoxy has greeter flexural strength than that of -45◦+45◦ composite. Yahaya *et al* [20] analysed the effect of fiber orientation on mechanical properties of Kenaf-Aramid hybrid composite. From the survey of the literature it has been obtained that orientation of fiber is a very important parameter to develop the mechanical characteristics of natural fiber reinforced composite but almost no investigation has been carried out to disclose the effect of fiber orientation on coconut midrib fiber. So we have chosen the coconut midrib for studying the influence of its orientation on flexural and impact strength and also on hardness. Therefore, the aim of this research work is finding new alternative of sports equipment (skateboard) application in prospects of long-lasting and economic concern as well as better physical or mechanical properties. The present work focused on the fabrication of jute - glass fiber based skateboard by using hand layup method. Later the mechanical performances of these composite have been investigated experimentally.

MATERIALS AND METHODS

Materials Collection

The materials used in this study were

- Coconut leaf midrib fiber as reinforcement.
- Epoxy resin (AW 106) as the matrix.
- Hardener ADH 160 to improve the interfacial adhesion and impart strength to the composites and
- The masking tape to facilitate realizing of mould agent.

The materials used in this study is shown in figure 1. A local chemical company supplied the hardener and the resign. The coconut leaf midrib fiber were extracted from the coconut leaf which is widespread in Bangladesh. A resin and hardener mixture of 3:1 was used to obtain optimum matrix composition. The physical properties of coconut midrib have been shown in Table -1[21]. Coconut is defined as a continuous natural fiber and more specifically a leaf fiber. It is readily available and popularly used as brooms. The mechanical properties of coconut midrib, epoxy resin and hardener are shown in Table -2 [21].

a b c

Fig. 1 Materials used in this study (a) Coconut Midrib fiber (b) Epoxy Resin (c) Hardener

Table -1 Physical Properties of Coconut Midrib

Component	Content/wt%
Cellulose	33.29±0.09
Hemicellulose	33.61±0.07
Lignin	19.87±0.08
Alcohol Benzene extractive	1.27±0.05
Ash	5.5±0.05

Table -2 Mechanical Properties of Fiber and Matrix

Properties	Coconut midrib fiber	Epoxy resin	Hard-ener
Density (g/cm^3)	1.3	2.54	1.2
Specific Gravity (gm./cc)	1.3	1.17	0.92
Poisson's ratio	—	0.4	—
Viscosity @ 25◦ C	—	50000	35000

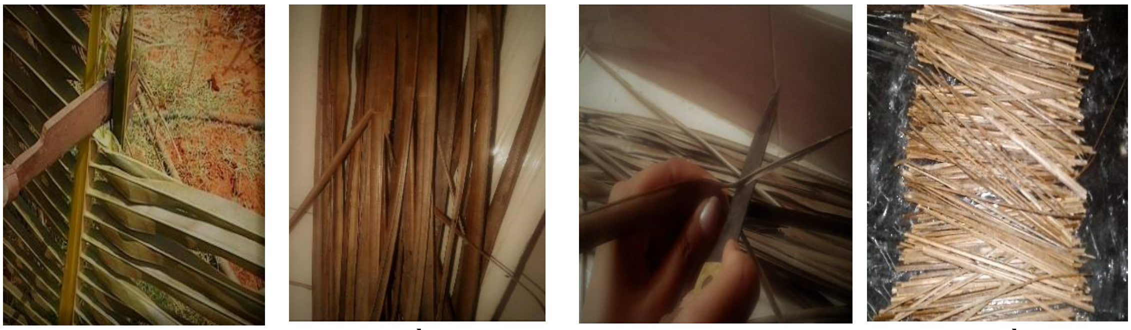
Extraction of Coconut Leaf Midrib Fibers

The coconut leaf midrib was extracted from the coconut leaf manually. The total extractions procedures of coconut midrib are shown in figure 2 and description of this procedure is as follows.

- At first the fully grownup and healthy green leaves were collected from the coconut tree.
- Using a sharp knife, the leaflets were trimmed from the fronds.
- Then the leaflets were dried in the sun for 1 week until completely dried.
- After that a knife was inserted between each midrib and the leaf and mid rib was gently separated from the leaf.
- After accumulating all the midribs, they were properly washed and dried in the ambient temperature for a day.

Composite Fabrication Procedure

A number of techniques exist in industries for manufacturing of composites such as compression molding, injection molding, vacuum molding, thermal expansion molding, autoclave molding and resin transfer molding. Among them the oldest, simplest and most conventional method is the open mold hand lay-up process. In this study, the composites were fabricated using the open mold hand lay-up process. The complete fabrication procedures are shown in figure 3.



a b c d

Fig. 2 Fiber extraction Procedure (a) Trimming coconut leaves (b) After drying (c) separation of the midrib from the leaves (d) Trimming into desired size

a b c

d e f

Fig. 3 Complete sequential process for fabrication (a) Mixing resin and fiber in appropriate proportion (b) Pouring of mixer in to the mold (c) Placing fiber on the mixture (d) Wrapping with masking tape (e) Force applying manually (f) 72 hours later

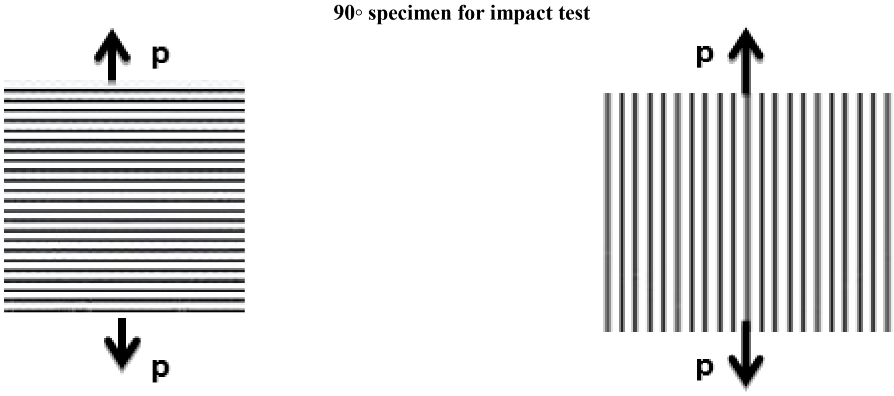
- First, a mold releasing agent was applied on the wooden mold surface.
- Then the resin and hardener mixture was prepared and stirred properly to make it homogenous.
- After that the mixture was poured on the mold and labelled properly so that no void could exist.
- Then the coconut midribs were placed on the resign mixture unidirectional and utmost uniformly.
- Then again another layer of resign and hardener mixture was applied onto it and then covered with a mold releasing agent after removal of air gaps with rollers.
- Finally, an approximate constant pressure was applied onto it with the help of two bricks.
- Curing was performed at the room temperature (25◦C) for 72 hours.
- After the fabricated part got completely hardened, it was removed from the mold and uneven edges were equally cut with the saw as per the required dimensions.

EXPERIMENTAL PROCEDURE

Two types of samples are prepared for flexural, impact and hardness testing named as 0^o Sample and 90° sample. The samples are shown in figure 4 and the loading direction of the test specimens are shown in figure 5. Flexural test generally known as three-point bending test was carried out as per ASTMD790. Composite specimens (120mm × 20mm × 5mm) were horizontally placed on two supports (each 20mm away from each corner points) and load was applied at the centre. The gauge placed under the specimen showed the displacements. The Tinius Olsen machine was used to perform the charphy impact test as per procedure mentioned in ASTM D256. Composite specimens were placed horizontally so that the hammer stroke the midpoint of the notch. The CRT reader gave the reading of impact strength. The Rockwell hardness test was carried out using a hardness testing machine. The testing machine is shown in figure 6. Table 3 shows the thickness, fiber orientation, and fiber content of the composite samples used for the investigation.

a **b** **c** **d**

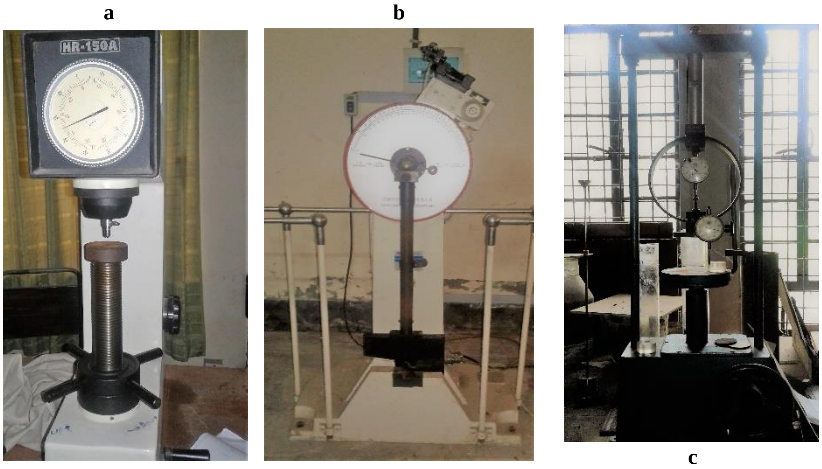
Fig. 4 Testing sample (a) 0◦ specimen for 3-point bending test (b) 90◦ specimen for 3-point bending test (c) 0◦ specimen for impact test (d) 90◦ specimen for impact test



a **b**

Fig. 5 Stacking sequence and loading direction of coconut midrib epoxy composite a) 90° b) 0º

a **b**



c

Fig. 6 Testing machine (a) Rockwell Hardness Tester (b) Impact Tester (c) 3-point Bending Tester

Table -3 Thickness, Fiber Orientation, and Fiber Content of Composite Samples

Sample ID	Thickness (mm)	Fiber orientation (deg)	Fiber and Matrix content (vol. %)	
			Fiber	Matrix
S1	5.10±0.3	0º	30	70
S2	4.90±0.3	0º	30	70
S3	5.30±0.3	0º	30	70
S4	4.86±0.3	90°	30	70
S5	4.94±0.3	90°	30	70
S6	5.10±0.3	90°	30	70

EXPERIMENTAL RESULTS AND DISCUSSION

Flexural Test

The composite specimens are subjected to three-point bending loading and the results have been analysed in this study. The flexural test results are shown in figure 7 and Table 4. According to the results, the fiber orientation of 0^0 composite samples is performing better than the 90º fiber orientation composite samples. The 0◦ specimens depict quite similar trends which may be indicated as shear failure according to Pothan *et al* [22]. The highest flexural strength was found in Sample S1 of 60.01 MPa, where S2 and S3 have fractures at respectively 36.51 and 40.21 MPa. On the other hand, the specimen 90◦ (Sample S4. S5 and S6) showing quite same trend displays a much lower fracture strength (8.41 MPa) than the 0◦ specimens. The reason behind this variation is that the 0◦ specimen will only break when one or many of its reinforcing fibers meet a breakage but the 90◦ specimen breakage takes place on the matrix. There may be also a possible reason that the interfacial bonding between the particles and matrix of 0◦ specimen is greater than that of the 90◦ specimen.

Table -4 Experimental Results of Different Composite Samples

Sample ID	Fiber Orientation (deg)	Flexural Strength (MPa)	Impact Strength (J/cm^2)	Hardness (HRC)
S1	0°	60.34	159.45	80
S2	0°	36.89	154.89	72
S3	0°	40.45	134.54	79
S4	90°	10.20	81.66	76
S5	90°	12.10	78.43	78
S6	90°	13.20	79.56	81

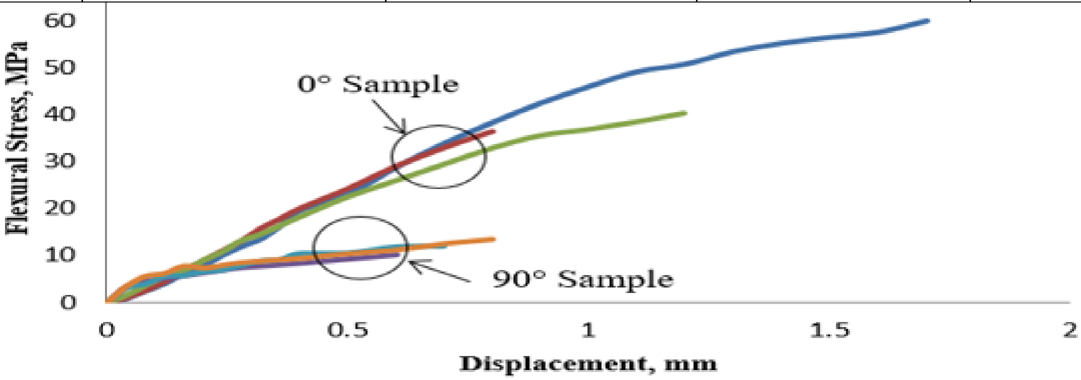


Fig. 7 Flexural strength vs. displacement curve

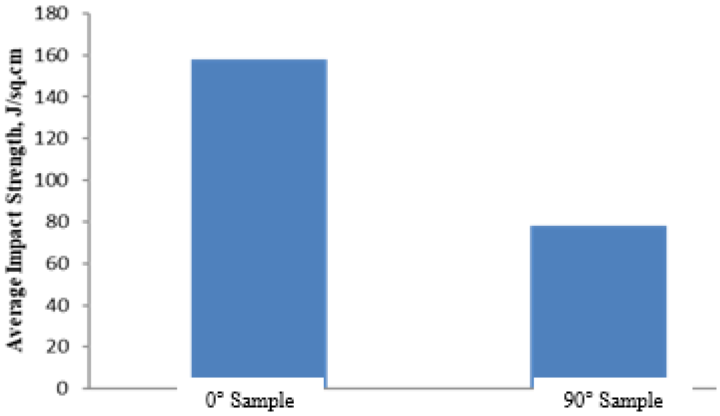


Fig. 8 Impact strength of different specimen with different fiber orientation

Fig. 9 The edges after impact test

Impact Test

The energy absorbed by the specimens during fracture as well as the toughness can be measured from the Charpy impact test. The results of impact test of different specimen with different fiber orientations are shown in Table 4 and figure 8**.** According to the results, the fiber orientation of 0^0 composite samples exhibit better impact strength than the 90° fiber orientation composite samples. The average impact strength was 81.667 J/cm^2 found in 90◦ specimen. Whereas the average impact strength of 0◦ specimen is found to be 154.1 J/cm^2. Due to the fiber loading direction, fracture takes place on matrix for 90° specimen whereas, fracture takes place on both matrix and fiber for 0° specimen. This might be the causes of low impact strength of 90° specimen. Moreover, ductility can be determined from the impact test result [23]. The specimen showed jagged edges (figure 9) and it can be defined as ductile fracture and may be caused by nucleation, growth, and coalescence of voids.

Hardness Test

The hardness test results are shown in Table 4. It is crystal clear that the fiber orientation has no significant influence on hardness. The likely reason behind the negligible variation may be the indenture was not exactly on the fiber all the time.

CONCLUSIONS

The outcome can be concluded in three ways

- The fiber orientation has significant factor on flexural strength with 0^0 specimen obtaining higher values.
- Fiber orientation has also prominent influence on impact strength.
- Hardness is almost not affected by fiber orientation.

The fabrication of coconut midrib reinforced composite and its mechanical performance give rise to the probability of using it as important alternative.

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