The Mechanical Properties of the Sea Pandan Leaves (Pandanus Tectorius) Fiber-Reinforced Epoxy Composite Were Assessed Using Bending Tests

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Abstract. The aim of this study was to conduct a bending experiment to study the mechanical properties of natural fiber composites made from sea pandanus leaves (Pandanus Tectorius). The method for making composites by hand lay-up and vacuum bagging. The utilized fiber is oriented at zero and ninety degrees. Bending testing based on ASTM D7264. The results of the bending tests show that the vacuum bag method produces composites with a higher bending strength and modulus of bending elasticity than the hand lay-up method. The bending strength of composites with zero-degree fiber orientation is greater than that of composites with ninety-degree fiber orientation.

Keywords: composite, sea pandanus leaf natural fiber, bending strength

1 Introduction

Today's engineering world has seen a very rapid development of composite materials. One benefit of composites is that they outperform metals in terms of strength-to-weight ratio [1], [2]. In composite materials, a variety of fibers, primarily synthetic fibers created through chemical processes like glass and carbon fibers, are utilized as reinforcement. There are, however, other fibers made from natural fibers. Natural fibers have advantages over synthetic fibers, such as being cheaper, less dense, more affordable, recyclable, safe for the environment and human health, and having better mechanical qualities [3].
While using natural composite materials can able to optimize 60 to 80% of weight than aluminium matrix composites. Polymer based fiber composites are achieved a

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better impact strength compared with epoxy based fiber composites, and epoxy composites have reasonable tensile properties [4].
Adding more natural fibers in epoxy resin composites will optimize the voids during the fabrication of composite materials and improves better flexural properties [5,6]. Alkali treated natural fibers comparatively affects both tensile and flexural property [7,8].
Sea pandan leaf fiber is a natural fiber that is widely accessible (Pandanus Tectorius). Since sea pandanus is an indigenous plant of Eastern Australia and the Pacific Islands, it primarily thrives along tropical coastlines. This monocot plant can be found in Indonesia on the Sulawesi coast, the southwest coast of Sumatra, and the south coast of Java. The goal of using sea pandan leaves as a composite material is to use less synthetic fiber and make better use of pandan leaves, which are nevertheless frequently thrown away. A cell's tensile strength is provided by cellulose; hence, the more cellulose there is, the more flexible the material will be [9].
There have been numerous studies on sea pandanus leaf fibers. Composites with a composition of 30% marine pandanus leaf filler and 70% matrix have the best characteristics for further development compared to other compositions (40% marine pandanus leaf filler and 60% matrix and 50% marine pandanus leaf filler and 50% matrix) because they have values of water content, density, porosity, and water absorption that are in accordance with applicable standards [10].
The highest tensile strength was found to be at woven angles of $0^0/90^0$ and $45^0/-45^0$ with the addition of pressure of 60 N/mm2 and a pressing time of 30 seconds in the study of the relationship between woven angle and pressing process on fiber orientation and tensile strength in laminate composites with sea pandanus fiber. The tensile strength at woven angle $0^0/90^0$, however, is higher than at woven angle $45^0/-45^0$. The fraction of sticky weight in the specimen decreases with increasing application pressure. This occurrence will result in the composite showing signs of delamination [11].
From the explanation above, it is obvious that this study concentrates on the manufacturing of sea pandanus leaf-epoxy composites with natural fiber reinforcement in order to collect data regarding the impact of composite manufacturing methods and the usage of fiber direction on bending strength.

2 Research Methodology

This study was conducted using experimental methods. Manufacturing composites using hand lay-up and vacuum bag methods. Sea pandanus leaf fibers serve as reinforcement, and epoxy serves as the composite's matrix (binder). The fiber directions 0^0 and 90^0 were used in this study. Bending tests are performed using ASTM D7264.
The Universal Testing Machine (UTM), a grinder, a digital scale, a compression vacuum, a scraper, a ruler, a knife, some wooden chopsticks, a plastic cup, an air pentil, and a composite mold were all employed in this research. Sea pandanus leaf fiber, epoxy resin, hardener, 6% NaOH solution, sandpaper, plasticine, molding wax, double tip, and vacuum plastic are the materials required for this research.

Calculations Related to the Composite Manufacturing Process. Here are some calculations related to the composite manufacturing process:

1. The mass of sea pandanus leaf fiber (Pandanus Tectorius), based on the mold size of 250 mm x 200 mm x 5 mm, is 12 grams

2. Calculating the composite's volume after adjusting its dimensions to the mold that was manufactured $Volume\ of\ Mold = p \times l \times t = 25\ cm \times 20\ cm \times 0.5\ cm = 250\ cm^3$
3. Calculating the volume of sea pandanus (Pandanus Tectorius) leaf fiber in composites
$$= \frac{sea\ pandanus\ leaf\ fiber\ mass}{density\ of\ sea\ pandanus\ fiber}$$
$$= \frac{12\ gram}{0.96 \frac{gram}{cm^3}} = 12.5\ cm^3$$
4. Calculating the volume fraction of sea pandanus (Pandanus Tectorius) leaf fiber in composites
$$= \frac{fiber\ volume}{composite\ volume} \times 100\%$$
$$= \frac{12.5\ cm^3}{250 cm^3} \times 100\% = 5\%$$
5. Calculating the mass fraction of sea pandanus (Pandanus Tectorius) leaf fiber in composites
$$= \frac{fiber\ mass}{composite\ mass} \times 100\%$$
$$= \frac{12\ gram}{277\ gram} \times 100\% = 4.332\ \%$$
6. Calculating the volume of the matrix in composites
$$= Composite\ volume - Fiber\ volume$$
$$= 250\ cm^3 - 12.5\ cm^3 = 237.5\ cm^3$$
7. Calculating the volume fraction of the matrix in the composite
$$= \frac{matrix\ volume}{composite\ volume} \times 100\%$$
$$= \frac{237.5\ cm^3}{250\ cm^3} \times 100\% = 95\ \%$$
8. Identify the requirements for epoxy resin and hardener resin in the matrix when the ratio of the two is 2:1.
$$Epoxy\ Volume = \frac{2}{3} \times 237.5\ cm^3 = 158\ cm^3$$
$$Epoxy\ Requirement$$
$$= Epoxy\ Volume \times Density\ of\ Epoxy$$
$$= 158.3\ cm^3 \times 1{,}2\ gram/cm^3 = 189.96\ gram$$
$$Hardener\ volume = \frac{1}{3} \times 237.5\ cm^3 = 79.16\ cm^3$$
$$Hardener\ requirement$$

$$= Hardener\ Volume \times Density\ of\ Hardener$$
$$= 79.16\ cm^3 \times 0.97\ gram/cm^3 = 76.78\ gram$$

Composite Manufacturing Process with Hand Lay Up Method. The steps for manufacturing composite specimens using the hand lay-up method are as follows:
The fibers were cut according to the length of the mold, then the fibers were soaked in sea pandan leaves with 6% Alkali NaOH solution for 1 hour and dried under the hot sun for ± 1 day. To facilitate removal of the composite from the mold after the drying process, release wax is smeared on the mold and plasticine is applied to the edges of the mold. The drying process is carried out at ambient temperature for a period of approximately 6-12 hours. The composite was trimmed to fit the specimen's 160 mm x 15 mm x 5 mm dimensions. [12].

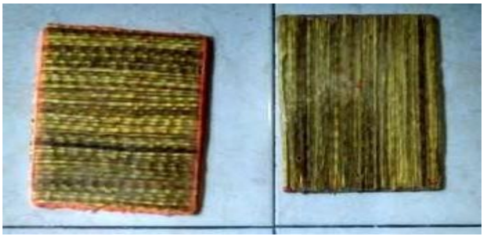

Fig. 1. Fiber Directions 0^0 and 90^0 of Sea Pandanus Leaf Fiber Composite

Composite Manufacturing Process with Vacuum Bag Method. The difference between the hand-layup approach and the vacuum bag method for manufacturing composite specimens occurs during the pressing stage. The vacuum bag method involves using a vacuum tool to press the material for around eight hours.
Figure 2 shows the sample after it has been sliced. Based on ASTM D7264, this specimen is ready to be tested for bending.

Fig. 2. Resulting Specimen from Cutting

3 Results and Discussion

Bending Test Results of Composite Specimens Using the Hand Lay-Up Method. Tables 1 and 2 show the dimensions and mechanical properties of bending test specimens manufactured using the hand lay-up method in the 0^0 fiber orientation. Specimens made by the hand lay-up method are coded specimen A.

Table 1. Dimension of Bending Test Specimen Using Hand Lay-Up Method for Fiber Direction 0^0

Specimen Code	Width (mm)	Thickness (mm)	Area (mm)	Deflection (mm)	Max Load (N)
A1 0°	13.060	4.680	61.120	3.620	29.6
A2 0°	14.340	4.100	58.790	3.290	28.5
A3 0°	15.980	4.300	68.710	10.230	88.6
A4 0°	16.920	3.910	66.160	3.230	53.1
A5 0°	17.460	5.580	97.430	3.980	103.4

Table 2. Mechanical Properties of Bending Test Specimens Using the Hand Lay-Up Method for Fiber Direction 0^0

Specimen Code	Bending Strength (MPa)	Bending Modulus of Elasticity (MPa)
A1 0°	8.060	214.362
A2 0°	9.240	310.067
A3 0°	23.380	239.549
A4 0°	16.020	574.194
A5 0°	14.840	301.626
Nilai Rata-rata	14.308	327.96
Standar Deviasi	6.129	143.497
Koefisien Variasi (%)	0.428	0.438

From the calculation of the bending strength of the sea pandanus leaf fiber composite using the hand lay-up method in the 0^0 fiber direction, the average value of the bending strength is 14.308 MPa with a standard deviation value of 6.129 (table 2).
Tables 3 and 4 show the dimensions and mechanical properties of bending test specimens manufactured using the hand lay-up method in the 90^0 fiber orientation.

Table 3. Dimension of Bending Test Specimen Using Hand Lay-Up Method for Fiber Direction 90^0

Specimen Code	Width (mm)	Thickness (mm)	Area (mm)	Deflection (mm)	Max Load (N)
A1 90°	14.1	3.4	47.94	5.64	35.5
A2 90°	13.93	4.93	68.67	1.57	15.7
A3 90°	13.24	4.92	65.14	5.53	16.7

A4 90°	13.08	4.62	60.43	7.56	34.5
A5 90°	14.98	4.38	65.51	2.13	9.2

Table 4. Mechanical Properties of Bending Test Specimens Using the Hand Lay-Up Method for Fiber Direction 90^0

Specimen Code	Bending Strength (MPa)	Bending Modulus of Elasticity (MPa)
A1 90°	16.990	399.765
A2 90°	3.630	213.529
A3 90°	4.060	67.107
A4 90°	9,640	124.709
A5 90°	2.490	120.874
Nilai Rata-rata	7.362	185.197
Standar Deviasi	6.051	130.942
Koefisien Variasi (%)	0.822	0.707

From the calculation of the bending strength of the sea pandanus leaf fiber composite using the hand lay-up method in the 90^0 fiber direction, the average value of the bending strength is 7.362 MPa with a standard deviation value of 6.051 (table 4).

Bending Test Results of Composite Specimens Using the Vacuum Bag Method

Tables 5 and 6 show the dimensions and mechanical properties of bending test specimens manufactured using the vacuum bag method in the 0^0 fiber orientation. Specimens made by the vacuum bag method are coded as specimen B.

Table 5. Dimension of Bending Test Specimen Using Vacuum Bag Method for Fiber Direction 0^0

Specimen Code	Width (mm)	Thickness (mm)	Area (mm)	Deflection (mm)	Max Load (N)
B1 0°	13.380	5.200	69.580	5.880	110.5
B2 0°	12.280	5.240	64.350	9.720	103.1
B3 0°	12.540	5.980	74.990	4.080	97.2
B4 0°	12.600	5.780	72.830	5.920	156.4
B5 0°	15.200	5.040	76.610	5.490	144.3

Table 6. Mechanical Properties of Bending Test Specimens Using the Vacuum Bag Method for Fiber Direction 0^0

Specimen Code	Bending Strength (MPa)	Bending Modulus of Elasticity (MPa)
B1 0°	23.820	352.367
B2 0°	23.860	211.337
B3 0°	16.910	312.569

B4 0°	28.970	381.686
B5 0°	29.150	474.756
Nilai Rata-rata	24.542	346.543
Standar Deviasi	5.002	96.362
Koefisien Variasi (%)	0.204	0.278

From the calculation of the bending strength of the sea pandanus leaf fiber composite using the vacuum bag method in the 0^0 fiber direction, the average value of the bending strength is 24.542 MPa with a standard deviation value of 5.002 (table 6).
Tables 7 and 8 show the dimensions and mechanical properties of bending test specimens manufactured using the vacuum bag method in the 90^0 fiber orientation.

Table 7. Dimension of Bending Test Specimen Using Vacuum Bag Method for Fiber Direction 90^0

Specimen Code	Width (mm)	Thickness (mm)	Area (mm)	Deflection (mm)	Max Load (N)
B1 90°	13.880	5.960	82.72	1.970	72.0
B2 90°	12.300	6.210	76.38	1.680	115.8
B3 90°	15.620	6.540	102.15	2.160	122.5
B4 90°	13.600	4.260	57.94	3.550	39.8
B5 90°	13.760	6.040	83.11	2.030	132.4

Table 8. Mechanical Properties of Bending Test Specimens Using the Vacuum Bag Method for Fiber Direction 90^0

Specimen Code	Bending Strength (MPa)	Bending Modulus of Elasticity (MPa)
B1 90°	11.380	434.692
B2 90°	19.05	824.675
B3 90°	14.310	457.188
B4 90°	12.590	376.946
B5 90°	20.580	759.410
Nilai Rata-rata	14.715	571.182
Standar Deviasi	4.091	205.079
Koefisien Variasi (%)	0.278	0.359

From the calculation of the bending strength of the sea pandanus leaf fiber composite using the vacuum bag method in the 90^0 fiber direction, the average value of the bending strength is 14.715 MPa with a standard deviation value of 4.091 (table 8).

Discussion. Table 9 displays the mechanical properties of the test results for both composite manufacturing methods and both fiber orientations.

Table 9. Mechanical Properties of Bending Test Specimens

Specimen Code	Average Value of Bending Strength (MPa)	Average Value of Bending Modulus of Elasticity (MPa)
A 0°	14.308	327.96
A 90°	7.362	185.197
B 0°	24.542	346.543
B 90°	14.715	571.182

Based on the test results, it is evident that sea pandanus leaf fiber composites manufactured using the vacuum bag method and having a 0° fiber direction have the greatest average value of bending strength, about 24.542 MPa. The lowest average value of bending strength, 7.362 MPa, is found in the sea pandanus leaf fiber composite manufactured using the Hand Lay Up manufacturing method, with the fiber direction at 90º (Figure 3).

Based on the test results, it can be shown that the sea pandanus leaf fiber composite's average bending elastic modulus, which was manufactured using the vacuum bag manufacturing method and a 90° fiber direction, is the highest, coming in at 571.182 MPa. The lowest average value of bending elastic modulus, 185.197 MPa, is found in the sea pandanus leaf fiber composite manufactured using the hand lay-up manufacturing method with a 90° fiber orientation (Figure 4).

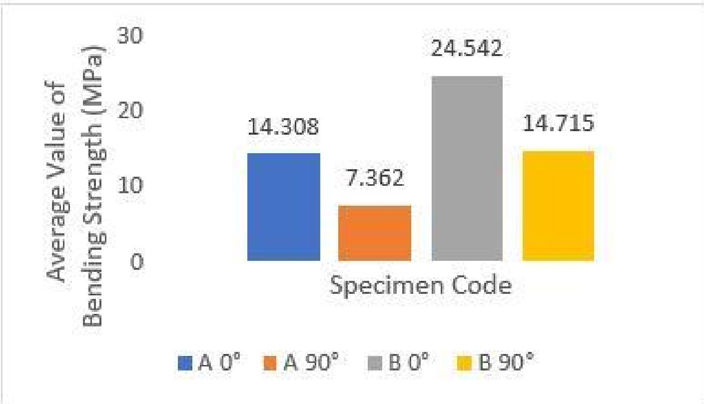

Fig. 3. Average Bending Strength of Sea Pandanus Leaf Fiber Composites

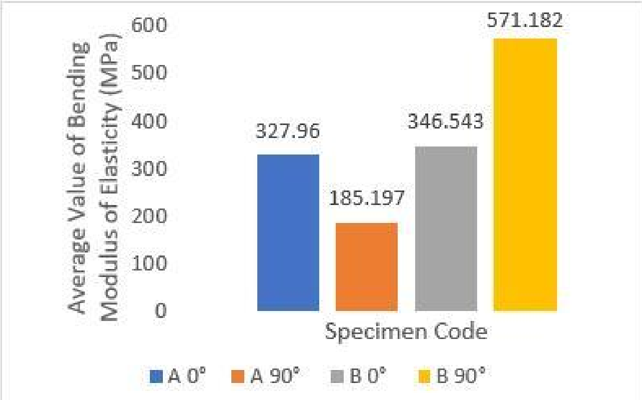

Fig. 4. Value of Bending Modulus Elasticity of Sea Pandanus Leaf Fiber Composite

4 CONCLUSIONS

The specimen has been made according to ASTM D7264. The results showed that, in comparison to composites created using the hand lay-up method, composites made using the vacuum bag method have a higher bending strength and bending modulus of elasticity. Composites with a 0° fiber direction have a higher bending strength than composites with a 90° fiber orientation. For further research, other variations of the direction of composite fiber can be used.

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References

1. Ronald F. Gibson, Principle of Composite Materials Mechanics, 4th Edition. Department of Metallurgical Engineering, Utah, 1994.
2. H. I. Firmansyah, A. Purnowidodo, and S. A. Setyabudi, "Pengaruh mechanical bonding pada aluminium dengan serat karbon terhadap kekuatan tarik fiber metal laminates," Jurnal Rekayasa Mesin, vol. 9, no. 2, pp. 127–134, 2018.
3. Z. Zulkifli, H. Hermansyah, and S. Mulyanto, "Analisa Kekuatan Tarik dan Bentuk Patahan Komposit Serat Sabuk Kelapa Bermatriks Epoxyterhadap Variasi Fraksi Volume Serat," JTT (Jurnal Teknologi Terpadu), vol. 6, no. 2, pp. 90–95, 2018.
4. Ajith Gopinath, Senthil Kumar M, Elayaperumal A. Experimental Investigations on Mechanical Properties of Jute Fiber Reinforced Composites with Polyester and Epoxy Resin Matrices. Procedia Engineering 97 (2014) 2052 – 2063.

5. Atiqah Afzaluddin, Mohammad Jawaid, Mohd Sapuan Salit, Mohamed Ridwan Ishak. Physical and mechanical properties of sugar palm/glass fiber reinforced thermoplastic polyurethane hybrid composites. 2019;8(1):950–959.
6. Vivek Mishra, Sandhyarani Biswas. Physical and Mechanical Properties of Bi-directional Jute Fiber epoxy Composites. Procedia Engineering 51 (2013) 561 – 566.
7. Jonathan B. Dawit, Hirpa G. Lemu, Yohannes Regassa, Adugna D. Akessa. Investi-gation of the mechanical properties of Acacia tortilis fiber reinforced natural compo-site. Materials Today: Proceedings 38 (2021) 2953–2958.
8. T. Alomayri, I.M. Low. Synthesis and characterization of mechanical properties in cotton fiber-reinforced geopolymer composites. Journal of Asian Ceramic Societies 1 (2013) 30–34.
9. G. Gusmailina, "Peningkatan Teknik Pengolahan Pandan (Bagian I): Pewarnaan Dan Pengeringan," Jurnal Penelitian Hasil Hutan, vol. 28, no. 1, pp. 66–76, 2010.
10. N. Nuryati, R. R. Amalia, and N. Hairiyah, "PEMBUATAN KOMPOSIT DARI LIMBAH PLASTIK POLYETHYLENE TEREPHTHALATE (PET) BERBASIS SERAT ALAM DAUN PANDAN LAUT (Pandanus…," J. Agroindustri, vol. 10, pp. 107–117, 2020.
11. K. Anam, A. Purnowidodo, and S. A. Setyabudi, "Pengaruh Woven Angle dan Proses Penekanan terhadap Tegangan Tarik pada Natural Fiber Laminate Composite," Jurnal Rekayasa Mesin, vol. 9, no. 3, pp. 155–162, 2018.
12. "ASTM D7264 Standard Test Method for Flexural Properties of Polymer Matrix Composite Materials." American Society of Testing Materials, West Conshohocken, 2015.