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Effect of Bending Properties on the Impact Strength of Pineapple Leaf Fiber-Polyester Composites

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ABSTRACT
Composite is a material made by combining two or more materials with different mechanical characteristics. This research aims to determine the characteristics and effects of adding pineapple leaf fibers with polyester on the quality of the resulting composite material. The composition variations between pineapple leaf fibers and polyester resin in composite material manufacturing are 30%:70% (sample A), 40%:60% (sample B), 50%:50% (sample C), 60%:40% (sample D), and 70%:30% (sample E). The composite material is molded using a hot press machine with a pressure of 0.1 MPa and a temperature of 150℃ for 15 minutes. The resulting composite material characteristics for samples A, B, C, D, and E, in terms of flexural test values, are 26.684 MPa, 30.489 MPa, 39.016 Mpa, 45.912 Mpa, and 49.356 MPa, respectively, while the impact test values are 0.0278 J/mm², 0.0297 J/mm², 0.0304 J/mm², 0.0306 J/mm², and 0.0322 J/mm², respectively. The higher the composition of pineapple leaf fibers used, the higher the specimens' flexural and impact test values.

Keywords: Composite material, Pineapple leaves, Polyester, Bending, and Impact

ABSTRAK
Komposit merupakan material yang dibuat dengan menggabungkan dua atau lebih material dengan karakteristik mekanik yang berbeda. Penelitian ini bertujuan untuk mengetahui karakteristik dan pengaruh penambahan serat daun nanas dengan polyester terhadap kualitas material komposit yang dihasilkan. Variasi komposisi antara serat daun nanas dan resin polyester pada pembuatan material komposit yaitu 30%:70% (sampel A); 40%:60% (sampel B); 50%:50% (sampel C); 60%:40% (sampel D) dan 70%:30% (sampel E). Material komposit dicetak menggunakan mesin hot press dengan tekanan 0,1 MPa dan suhu 150 ℃ selama 15 menit. Hasil karakteristik material komposit yang dihasilkan pada sampel A, B, C, D dan E masing-masing untuk nilai uji lengkung adalah 26,684 Mpa, 30,489 Mpa, 39,016 Mpa, 45,912 MPa dan 49,356 MPa, sedangkan nilai uji impak adalah 0,0278 J/mm^2, 0,0297 J/mm^2, 0,0304 J/mm^2, 0,0306 J/mm^2, dan 0,0322 J/mm^2. Semakin bertambahnya komposisi serat daun nanas yang digunakan maka akan semakin meningkat nilai uji kelengkungan dan impak pada spesimen tersebut.

Kata kunci: Material kompsoit, Daun nanas, Polyester, Uji Lengkung, dan Impak

1. Introduction

Waste is an issue requiring careful consideration in both management and utilization. The environment and communities will be disrupted and threatened if waste problems are not promptly addressed. Therefore, taking several initiatives to manage waste and make decisions that benefit the greater good is crucial. Pineapple leaf waste should be transformed into something valuable that adds economic value to pineapple farmers. One way to address the leftover materials from pineapple leaves is to utilize pineapple leaf fibers. The advantages of pineapple leaf fibers include reducing production costs and being environmentally friendly while still producing quality products [1]. Pineapple leaf fibers, rich in cellulose content (ranging from 69.6–71%), are relatively inexpensive and abundant, making them highly suitable for composite material production [2]. Other types of waste that can be utilized for composites include pineapple leaves, sugarcane bagasse, palm fibers, and other agricultural residues.

Composites are microscopic substances composed of two or more different materials combined in various ways, such as integrating fibers and resin. Fiber-reinforced composite materials are widely used in technical applications due to their higher specific strength and stiffness compared to other engineering materials. Additionally, composites possess lower density, greater strength, corrosion resistance, and cost advantages [3]. Composites can be formed from two different materials, such as a combination of fiber and resin [4]. The properties of composite materials are a blend of the matrix and reinforcement or filler, where each constituent provides distinct characteristics. Reinforcement materials must improve the properties of the matrix to form a high-quality composite material [5].

Polyester is a type of polymer matrix widely used in modern composites, particularly as a thermoset resin [6]. Polyester resin has unique features such as being dyeable, water-resistant, transparent, weather-resistant, and higher rigidity than other thermoset resins. Polyester exhibits superior electrical properties compared to other thermoset resins [7].

Previous studies have highlighted the versatility of natural fibers in composites. For example, Wahyudi (2021) used sugarcane bagasse fibers with a polyester matrix to create motorcycle body covers, focusing on bending and impact strength [8]. Supriyatna (2018) developed epoxy composites reinforced with pineapple fibers for automobile interiors, following tensile test standards (ASTM D 638-14) and impact test standards (ISO-179-2010) [9]. Similarly, Samlawi (2017) investigated palm fiber composites for motorcycle body covers, conducting impact tests according to ASTM D5942-96 and tensile tests based on ASTM D 638-03 standards [10].

Based on these conditions, research is needed to determine the effect of bending test values on the impact strength of composites made from pineapple leaves and polyester. This study aims to enhance the quality of composite materials by utilizing pineapple leaves and polyester. The parameters to be tested include bending and impact properties.

2. Materials and Methods

2.1. Tools and materials

The tools used in this research included plastic containers, knives, scissors, spatulas, a digital scale, a 5000 ml measuring cylinder, calipers, carbon masks, latex gloves, a rectangular mold (dimensions: 10 cm × 2 cm × 1 cm), a hot press machine, an oven, a universal testing machine (UTM), and an impact testing machine (ITM).

The materials used in this study were pineapple leaf fibers, polyester resin, catalyst, wax, aluminum foil, distilled water, and NaOH.

2.2. Research procedures

The preparation of raw materials for composite material production begins with collecting pineapple leaves from pineapple stalks. The pineapple leaves are scraped to extract the fibers. The fibers are soaked in a solution of 250 grams of NaOH dissolved in 5 liters of distilled water for 2 hours. The fibers are then washed thoroughly with running water until clean. Drying is carried out using an oven at 60°C for 23 hours. The fibers are cut into uniform lengths of 10 cm to ensure consistency and homogeneity. This process yields pineapple leaf fibers as the raw material for composite material research. Then, the raw materials are weighed with variations in the composition of pineapple leaf fibers and polyester resin as follows: Sample A (30%:70%), Sample B (40%:60%), Sample C (50%:50%), Sample D (60%:40%), and Sample E (70%:30%). Polyester resin is mixed with 1% hardener catalyst by resin volume. The molding process involves coating the mold with aluminum foil and applying wax evenly to facilitate sample removal. Pineapple leaf fibers are dipped into the resin and placed in the mold. Compression and heating are carried out using a hot press machine under a pressure of 0.1 MPa at 150°C for 15 minutes. Once the samples are removed from the mold, testing can be performed to determine density values, bending strength, and impact strength.

2.3. Characterization

The bending test results were based on the ASTM D790-02 method, and the impact test results were based on the ASTM D5942-96 method. The bending test is performed on a specimen by applying a load at the center of the beam while both ends are supported. This test is commonly known as the three-point bending test, with an alternative four-point loading method also available. At the loading point in the middle of the beam, the outer surface of the upper part of the specimen experiences compressive stress, while the outer surface of the lower part of the specimen undergoes tensile stress, with the axis of the specimen remaining normal. The stress magnitude is determined by the specimen thickness, bending moment, and moment of inertia of the test material's cross-section. The maximum tensile stress occurs at the outermost surface of the lower part of the specimen, parallel to the loading axis [11]. The bending test strength can be calculated using Equation (1).

$$\sigma = \frac{3\,PL}{2bd^2} \tag{1}$$

Where,
σ = Flexural strength (MPa) P = Load (N)
L = Length (mm)
b = Width of the specimen (mm)
d = Thickness of the specimen (mm)

In the impact test, the material is subjected to a sudden load. The parameter obtained from this test is the impact value (energy per unit area). This test determines the brittle properties of the material at low temperatures (e.g., cryogenic temperature range) and can be used to identify the transition temperature from ductile to brittle behavior. The impact energy is calculated by measuring the difference in the pendulum's swing height before and after the impact [12]. The impact strength can be calculated using Equation (2)

$$Impact = \frac{W}{b_i \times h_i} \tag{2}$$

Where,
W = Absorbed energy of the test specimen (J)
b_i = Width of the test specimen (mm)
h_i = Thickness of the test specimen (mm)

3. Results and Discussion

3.1. Bending Test Results Analysis

The data from the bending test of the composite material can be seen in Table 1.

Table 1. Bending test results.

Sample	**Code Sample**	**Bending Test (MPa)**	**Average Bending Test (MPa)**
	A1	30.475	
A	A2	26.865	26.684
	A3	22.714	
	B1	23.118	
B	B2	29.161	30.489
	B3	39.188	
	C1	39.730	
C	C2	46.203	39.016
	C3	31.116	
	D1	52.346	
D	D2	46.203	45.912
	D3	39.188	
	E1	41.963	
E	E2	59.902	49.356
	E3	46.203	

Table 1 presents bending test values (in MPa) for five sample groups (A, B, C, D, and E), each consisting of three sub-samples. The bending test values range from 22.714 MPa (A3, the lowest) to 59.902 MPa (E2, the highest). The average bending strength for each sample group increases as follows: A (26.684 MPa) < B (30.489 MPa) < C (39.016 MPa) < D (45.912 MPa) < E (49.356 MPa). Notably, some sample groups, such as B and D, show a wider variation in bending strength, with values ranging from 23.118 MPa to 39.188 MPa (B) and 39.188 MPa to 52.346 MPa (D).

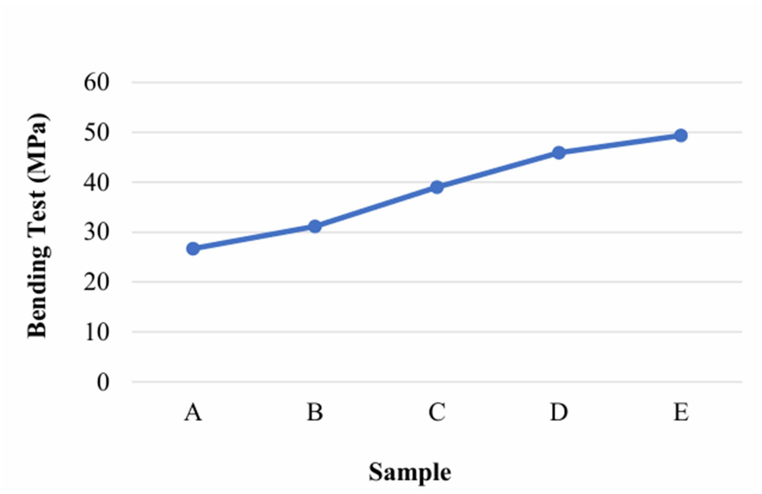

Figure 1. Graph of bending test results.

Figure 1 shows that as the composition of pineapple leaf fibers increases, the bending test values also increase. This is because adding fibers enhances the material's overall stiffness, making it more resistant to bending or deformation [13]. The highest bending test value was observed in Sample E, at 49.356 MPa, while the lowest was in Sample A, at 26.684 MPa. The increase in bending test values indicates good quality, as the material can withstand flexural loads without breaking. Compared to the study by Samlawi (2017), the bending test results show that all samples exceeded the bending strength range of the previous research, which was 37.79 MPa to 47.06 MPa [10].

3.2. Impact Test Results Analysis

The data from the impact test of the composite material can be seen in Table 2.

Table 2. Impact test results

Sample	Code Sample	Impact (J/mm^2)	Average Impact (J/mm^2)
A	A1	0.0276	0.0278
	A2	0.0282	
	A3	0.0274	
B	B1	0.0322	0.0297
	B2	0.0288	
	B3	0.0282	
C	C1	0.0322	0.0304
	C2	0.0307	
	C3	0.0288	
D	D1	0.0304	0.0306
	D2	0.0307	
	D3	0.0307	
E	E1	0.0322	0.0322
	E2	0.0322	
	E3	0.0322	

The table presents impact strength values (in J/mm^2) for five sample groups (A, B, C, D, and E), each consisting of three sub-samples. The impact strength ranges from 0.0274 J/mm^2 (A3, the lowest) to 0.0322 J/mm^2 (observed in multiple samples, including B1, C1, and all E samples, the highest recorded value). The average impact strength for each sample group follows an increasing trend: A (0.0278 J/mm^2) < B (0.0297 J/mm^2) < C (0.0304 J/mm^2) < D (0.0306 J/mm^2) < E (0.0322 J/mm^2). Sample E exhibits the highest and most consistent impact strength, with all sub-samples showing the same value of 0.0322 J/mm^2, indicating excellent uniformity in mechanical performance. The variations within groups such as B and C, where individual values fluctuate between 0.0282 J/mm² and 0.0322 J/mm², suggest a moderate dispersion of impact strength among sub-samples.

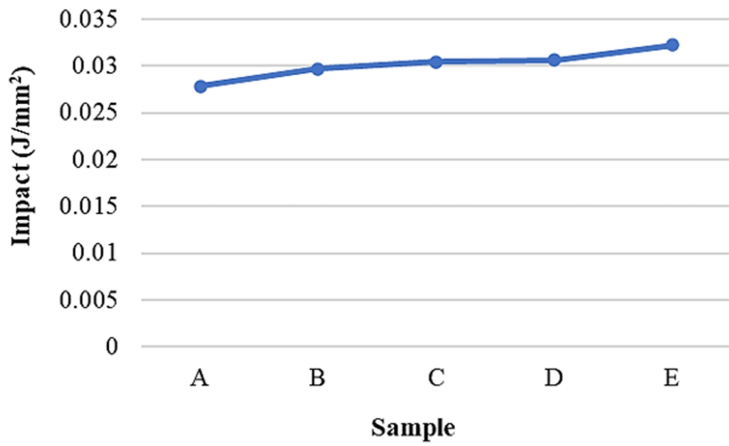

Figure 2. Graph of impact test results.

Figure 2 shows that as the composition of pineapple leaf fibers increases, the impact test values also rise. This is because the fibers can absorb the energy applied, thereby reducing overall material damage. The highest impact test value was observed in Sample E, at 0.0322 J/mm², while the lowest was in Sample A, at 0.0278 J/mm². These impact test values indicate high toughness; the higher the impact test value, the greater the energy the material can absorb before cracking or breaking [14]. Compared to the study by Mulyo (2018), the impact test results demonstrate that all sample values exceeded the range reported in the previous research, which was 0.00972–0.01657 J/mm² [15].

4. Conclusion

The characterization of composite materials made from pineapple leaf fibers and polyester in samples A, B, C, D, and E resulted in bending test values of 26.684 MPa, 30.489 MPa, 39.016 MPa, 45.912 MPa, and 49.356 MPa, respectively, while the impact test values were 0.0278 J/mm², 0.0297 J/mm², 0.0304 J/mm², 0.0306 J/mm², and 0.0322 J/mm². The results indicate that an increased proportion of pineapple leaf fibers leads to improved bending strength and impact resistance. Thus, incorporating pineapple leaf fibers into polyester composites enhances mechanical properties, making them stronger and more durable.

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