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Mechanical Traction Test of Pineapple Leaf Fiber-Epoxy Composite

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Abstract

Natural fiber-based composites are widely developed to replace materials in various industries, such as furniture and sound absorbers. One of the composite properties that is often considered for its use is mechanical property. In this study, the mechanical properties of pineapple leaf fiber-epoxy composites were studied using traction tests. The composite was made by mixing of small pieces of pineapple leaf fiber with epoxy resin, then the mixture was placed in a mold and pressed with a certain pressure at 100 °C for 2 hours. Traction tests were carried out on the pineapple leaf fiber-epoxy composites with two different epoxy concentrations (11 and 17 % wt), and different manufacturing pressure (0.22; 0.65; 1.09 MPa). The traction test results show that the maximum stress (ultimate tensile strength/UTS), elongation at break (EAB) and modulus of elasticity (E) increase with increasing epoxy content. Increasing the manufacturing pressure increases modulus of elasticity. However, the maximum UTS and EAB were shown by the composite with a manufacturing pressure of 0.65 Pa, not at the higher pressure (1.09 Pa).

Keywords: composite, epoxy, pineapple leaf fiber, traction test

INTRODUCTION

Environmental issues have attracted people around the world. Everything that humans do is related to their environment. For example, the use of wood from forests has become a public concern because of the decreasing number of forest trees. To overcome this problem, to replace wood products, natural fiber-based composites have now been developed everywhere [1]. The development of natural fiber-based composites can reduce deforestation, as well as utilize natural fiber waste.

Natural fiber mostly contains cellulose. Cellulose can be extracted from various plants, such as cotton, hemp, and wood. One of the natural fiber-based composites is pineapple leaf fiber-epoxy composite. Pineapple plantations are widely found in Indonesia. Effective area of pineapple plantations in Indonesia reaches 24,402 hectares [2].

Pineapple leaf fiber can reach a length of about 40 cm. Like other leaf fibers, pineapple leaf fiber consists of a collection of fiber bundles. Each bundle consists of multi-cellular fiber. Microscopically, pineapple leaf fiber cells have a diameter of about 10 μm and a length of 4.5 mm. The thickness of the pineapple leaf fiber cell wall is 8.3 μm [3].

Epoxy is one of the main thermoset matrix materials. Epoxy is a polymer that contains an epoxide group (one oxygen atom and two carbon atoms) in its chemical structure [4]. Even though epoxy resin is more expensive than polyester, it shows better moisture resistance, lower drying shrinkage (about 3%), higher maximum use temperature, and good adhesion to glass fiber [5].

Pineapple leaf fiber-composites have been studied for their use as sound absorbers [6-7]. Although the development of fiber-epoxy composites is intended

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for sound absorbing materials, it is also important to study their mechanical properties because their use requires certain mechanical characteristics. Therefore, in this study, the mechanical properties of pineapple leaf fiber-epoxy composites were studied using traction tests. Through traction tests, several mechanical quantities such as ultimate tensile strength (UTS), elongation at break (EAB), and modulus of elasticity (E) can be determined.

In general, the properties of composites depend on the mechanical properties of their components and their manufacturing procedures, so this study examines the effect of component composition and manufacturing pressure on the mechanical properties of the composites.

EXPERIMENTAL METHOD

The composite was prepared using a procedure as previously described [7]. The composite samples were made with different epoxy content and manufacturing pressures, as listed in Table 1.

Table 1. List of samples.

Sample name	Manufacturing Pressure (MPa)	Epoxy resin content (% wt)
E11P1	0.22	11
E17P1	0.22	17
E17P2	0.65	17
E17P3	1.09	17

The traction test was carried out using Mesdanlab Strength Tester (Universal Testing Machine) at *Politeknik Sekolah Tinggi Teknologi Tekstil Bandung*. The samples were tracted until break, as seen in Figure 1.

Figure 1. Traction testing was conducted until the sample break.

There are two sets of tests. The first is for composites with variations epoxy content, which was carried out at a rate of 50 mm per minute and test sample length of 75 mm. For each variation of epoxy content, the traction test was carried out for 6 samples. The dimensions of all samples are shown in Table 2.

Table 2. The dimensions of samples with different epoxy content for traction tests.

E11P1

Sample No	Thickness (mm)	Width (mm)	Cross section area (mm^2)
1	17.55	28.95	508.0725
2	17.55	28.95	508.0725
3	12.1	23.8	287,98
4	12.1	23.8	287.98
5	12.1	23.8	287.98
6	14.4	27.95	402.48

E17P1

Sample No	Thickness (mm)	Width (mm)	Cross section area (mm^2)
1	14	28.6	400.4
2	14	28.6	400.4
3	13.75	28.7	394.625
4	13.75	28.7	394.625
5	13.55	24.8	336.04
6	13.55	24.8	336.04

Second, the test was carried out for samples prepared with different pressure manufacturing. In this test, a rate of 300 mm per minute was used, and the length of the test sample was 50 mm. The test data was taken from two tests for each pressure variation. The dimensions of all samples are shown in Table 3.

Table 3. The dimensions of samples that were prepared using different manufacturing pressures for traction tests.

E17P1

Sample No	Thickness (mm)	Width (mm)	Cross section area (mm^2)
1	5.8	24.50	142.10
2	5.8	24.50	142.10

E17P2

Sample No	Thickness (mm)	Width (mm)	Cross section area (mm^2)
1	3.9	24.65	96.14
2	3.9	24.65	96.14

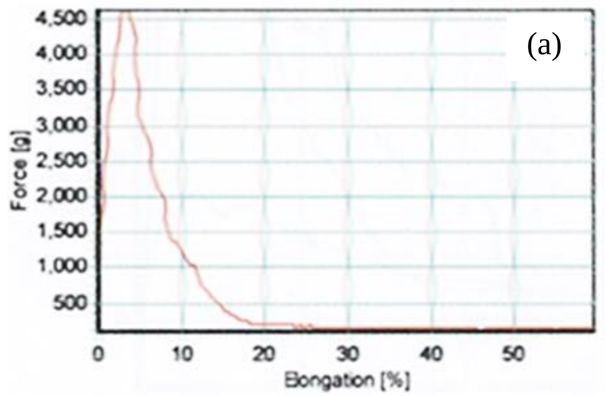
E17P3

Sample No	Thickness (mm)	Width (mm)	Cross section area (mm^2)
1	3.75	24.25	90.94
2	3.75	24.25	90.94

RESULTS AND DISCUSSION

Traction Testing of composite containing different epoxy content

Figure 2 shows curves of traction test result for samples E11P1 and E17P1. Each curve shows maximum force. At this maximum force, the sample begins to experience damage, so that the traction force continues to decrease.



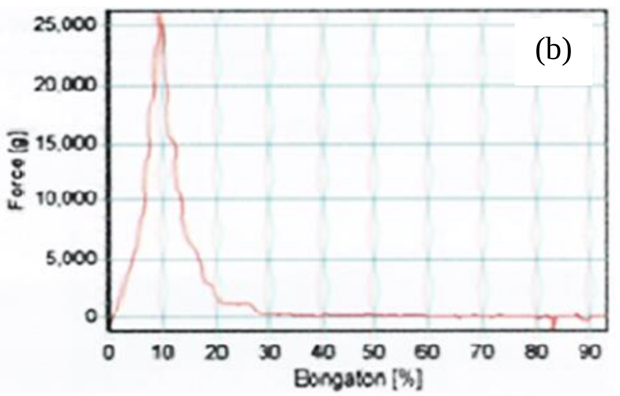


Figure 2. Example of traction curve of (a) E11P1, (b) E17P1. The sample length is 75 mm and the traction rate is 50 mm/minute.

The complete Traction test data of each sample are shown in Table 4. From six samples for each variation of epoxy concentration, the range of maximum force values for both concentrations are quite large, but it should be noted that the maximum force does not describe the characteristics of the material because it depends on the dimensions of the material. The quantity that better represents the characteristics of the material is the maximum stress (Ultimate tensile strength/UTS).

Traction test data in Table 4 were then processed to obtain maximum stress (UTS), elongation at break (EAB) and modulus of elasticity (E). UTS is obtained from maximum force divided by the cross-sectional area of the sample (thickness × width). Extension at break (rupture) is calculated by multiplying the time break with traction rate. EAB (%) is calculated by dividing extension at break by the initial length, followed multiplying by 100 [8]. The modulus of elasticity is calculated as the gradient of the force curve against elongation, which is determined manually from the curve print out, divided by the cross-sectional area.

Table 4. Traction test data of samples with different epoxy resin content.

E11P1

Sample No	Fmax (gf)	max elongation (%)	time break (s)
1	1477	14.4	13
2	1180	3.6	3.2
3	785	3.2	2.9
4	5070	3.6	3.2
5	4777	3.6	3.2
6	4086	2.35	2.1
average	2895.83	5.13	4.60

E17P1

Sample No	Fmax (gf)	max elongation (%)	time break (s)
1	195	12	10.8
2	2855	7.2	6.5
3	10340	3.6	3.2
4	590	27.2	24.5
5	26301	9.98	9
6	7684	6.8	6.1
average	7994.17	11.13	10.02

Average values of maximum stress, elongation at break and modulus of elasticity are shown in Table 5.

Table 5. Average values of maximum stress (UTS), elongation at break (EAB) and modulus of elasticity (E) of samples with different epoxy resin content.

Sample	UTS (kPa)	EAB (%)	E (MPa)
E11P1	8.72	5.11	0.26
E17P1	22.74	11.13	0.92

Table 5 shows that the addition of epoxy content increases the values of UTS, EAB and E. The increase in UTS and E is likely related to the geometry of the composite components. As we know, the dimension of pineapple leaf fibers in the composite is small while epoxy resin acts as a binder/matrix. Therefore, as expected, more epoxy content results in increasing stiffness and higher ability to resist external force. On the other hand, pineapple leaf fibers basically have the potential to experience a greater EAB than epoxy resin. However, the measurement results show that the composite containing higher epoxy content shows greater EAB. If the bond between the fiber and epoxy is good enough, then this result may be caused by the irregular orientation of the fibers in the composite.

Traction testing of composites prepared with different pressure

There are two samples for each manufacturing pressure. As an example, Figure 3 shows curves of traction test result for samples E17P1. Like curves in Figure 2, the traction test curves of composites prepared with different pressure also show maximum force. But different with curves in Figure 2 where the traction rate is 50 mm/minute, the curves in Figure 3 were obtained using higher traction rate: 300 mm/minute.

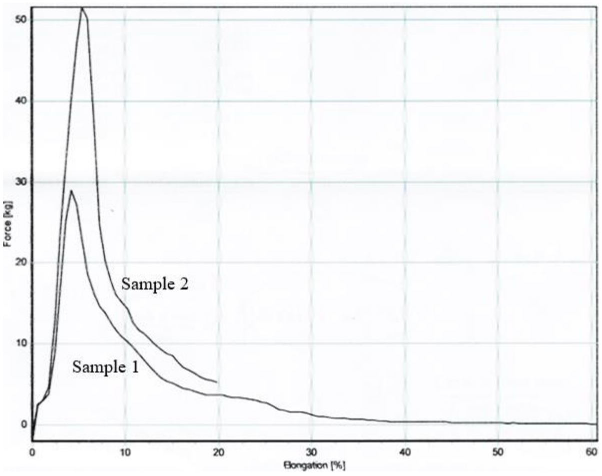


Figure 3. Force versus elongation curves of sample E17P1. The traction rate is 300 mm/minute.

Table 6. Traction test data of samples with prepared using different manufacturing pressures.

E17P1

Sample No	Fmax (kgf)	max elongation (%)	time break (s)
1	29.156	4.2	0.40
2	52.848	5.4	0.50
average	41.002	4.8	0.45

E17P2

Sample No	Fmax (kgf)	max elongation (%)	time break (s)
1	83.188	7.8	0.80
2	60.582	6.6	0.70
average	71.885	7.2	0.75

E17P3

Sample No	Fmax (kgf)	max elongation (%)	time break (s)
1	19.305	4.8	0.50
2	34.082	5.4	0.50
average	26.694	5.1	0.50

The complete Traction test data of each sample are shown in Table 6. As explained in the above section, rather than maximum force, the quantity that better represents the characteristics of the material is the maximum stress (Ultimate tensile strength/UTS). Traction test data in Table were processed using the above method to obtain average values of UTS, EAB and E. The results are shown in Table 7.

Table 7. Average values of maximum stress (UTS), elongation at break (EAB) and modulus of elasticity (E) of samples prepared with different manufacturing pressures.

Sample	UTS (kPa)	EAB (%)	E (MPa)
E17P1	288.54	4.5	8.12
E17P2	747.75	7.5	15.65
E17P3	295.54	5.0	18.47

The composite with the largest UTS and EAB values was produced by manufacturing pressure of 0.65 MPa. Increasing the pressure from 0.65 MPa to 1.09 MPa did not increase the UTS and EAB, but both quantities decreased. However, the elastic modulus increases with increasing manufacturing pressure. This is likely because of increasing manufacturing pressure results in denser composite so that the distance between molecules becomes closer. This condition could give greater interaction between molecules so that the composite becomes stiffer.

Furthermore, from Tables 4 and 7, the elastic modulus value shown by the pineapple leaf-epoxy composite depends on a test parameter (i.e. traction rate). Several studies have shown that the mechanical properties of natural fiber composites depend on the extension rate [9-10]. For E17P1, both UTS and E which were obtained with a large pulling rate (300 mm/minute) is about 10 times greater than those with a lower rate (50 mm/minute). This result is in line with those previously presented, where for natural fiber composites, a significant increase in extension rate results in increasing ultimate stress and modulus elasticity. This is due to the shorter stress relaxation time [10]. As E represents stiffness, this means that higher extension rate makes the material stiffer. On the other hand, it is noted from this study that increasing strain rate causes decreases EAB. Low EAB values are usually shown by more brittle materials.

CONCLUSION

From this study it can be concluded that the mechanical characteristics of pineapple leaf-epoxy resin composite are influenced by composition of composite's components, manufacturing process and traction test parameters (i.e. traction rate). The higher the epoxy content, the greater the UTS, EAB and E values. Higher manufacturing pressure gives greater value of modulus of elasticity but not for UTS and EAB. Composite with highest UTS and EAB values are produced with manufacturing pressure of 0.65 MPa, not at higher pressure (1.09 MPa). Furthermore, it is concluded that the pineapple leaf-epoxy composite shows higher UTS and E, but lower EAB, when it is tested with higher traction rate.

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