Flexural Property and Water Content of Unidirectional Polypropylene/ Subang Pineapple Leaf Fiber Composites

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Abstract. The development of natural fiber reinforced composite research has shown significant results. Pineapple leaf fiber reinforced composites for non-structural applications provide added value for Subang pineapple leaf fiber (PALF) waste. This study aimed to observe flexural strength, water absorption and desorption of composites which referred to the Indonesian National Standard (SNI) for composite board. Alkali treatment on Subang PALF was performed to improve the interface bonding between PALF with polypropylene (PP), in which the PALF was soaked in 5% NaOH solution for 24 hours. Treated PALF and PP sheets were fabricated using compression molding (hot press) technique with the variation of fiber fraction to polypropylene were 20 wt%, 30 wt% and 40 wt%. Flexural property, desorption and absorption water tests were conducted on PP and PP/PALF composites, and Optical Microscope (OM) observation was performed on the surfaces after the flexural test was conducted. The highest flexural strength and flexural modulus were (4.89 ± 0.37) MPa and (1.13 ± 0.43) MPa respectively, these values shown an increased respectively by 153.37 % compared to the pure PP. Then the desorption and the absorption water tests were (1.08 ± 0,12) % and (8.83 ± 3,35) % respectively. The morphology of flexural tested composites indicated that matrix failure; and it showed that there was a strong interface bonding between the fiber and matrix.

1. Introduction

Technological developments and awareness of environmental conditions have resulted in some types of material considered to be environmentally unacceptable. Indonesia has many types of natural fiber and these fiber have the potential to be developed as raw materials in several industries such as pineapple, hemp, kenaf, bamboo because of its advantages of having low density, biodegradation, environmental friendliness and lower production costs than synthetic fibers [1], [2]. Cellulose from fibers act as a composite reinforcement replacing synthetic fibers[2]. Recycle materials that are considered waste into materials that have higher economic value and as an alternative way to reduce environmental damage. Pineapple leaf fiber (PALF) has a cellulose content of about (70-8%), lignin (5-12%) and ash (1.1%) [3].

PALF has the potential for better mechanical properties compared to other types of fibers which have lower cellulose content such as jute fiber [4]. Problems occurred when combining the polymer matrix and the natural fiber got a poor adhesion bonding between matrix and fiber, thereby reducing the load transfer capability from the matrix phase to the fiber phase [4], [5]. It is necessary to make chemical modifications to the fibers with the purpose to increasing the interface bond between the polymer-fibers, namely by alkaline treatment. Alkaline treatment aimed to remove lignin, wax, oil, and other impurities that interfere with cellulose from natural fibers by soaking the fibers into a chemical solution. The effect
of alkaline treatment on fiber is to reduce the elasticity of the fiber so that the tensile strength will increase [6]. The dried fiber was purpose to minimize air bubbles during composite fabrication. Previously, PP/PALF20, PP/PALF30 and PP/PALF40 composites that were fabricated by compression molding method were prepared Rana Hafizah et al [7]. The PP/PALF30 composites had the optimum properties in tensile strength and deflection temperature. Research on flexural and diffusion properties on PP/Subang PALF composites ha not conducted yet. The desorption water test was the novelty of research from no one who analyzed the desorption water in polymer reinforced pineapple fibers or other natural fibers composite. So that, the aimed of this research was to obtain flexural strength, desorption and absorption rate of the PP/Subang PALF composites.

2. Experimental method

2.1 Alkaline treatment
PALF was soaked in 5% NaOH solution for 5 hours at room temperature 25°C. The fiber was washed in distilled water until the fiber was clear from NaOH and the fiber color was changed to white. Then, the fiber was stored at room temperature 25°C for 24 hours, and then dried at 75°C for 24 hours. Single fiber test on untreated and treated PALFs were carried out in bundles with a length of 5 cm and a width of 0.5 cm specimen size, according to SNI 08-1112-1989 standard.

2.2 Composite fabrication
PP pellets were processed into sheets by compression molding method with a temperature of 190°C. Composites were fabricated liked sandwiches; the fibers were unidirectional arrange in between the PP sheets. The fiber fraction to the weight of PP were 20 wt%, 30 wt% and 40 wt%. The composites were fabricated by compression molding method with a temperature of 190°C with a pressure of 0 MN/m² for 10 minutes and 4.9 MN/m² for 10 minutes. The results of composites fabrication were identified PP, PP/PALF20, PP/PALF30 and PP/PALF40.

2.3 Flexural test
Three-point bending test was conducted according to ASTM D7264 on a Universal Testing Machine (UTM). The specimens were pressed transversally in the middle at a speed of 10 mm/minute until the specimens reached the maximum curve point. Then the fractured specimens were observed at its curved point by the Optical Microscope.

2.4 Water Content test
Water content test was performed using SNI 01-4449-2006 reference to the method of drying ovens and soaking in water for 5 specimens. The desorption composite specimens were heated with a temperature of 103°C for 24 hours. The absorption composite specimens were soaked in water at 25°C water for 24 hours, with each specimen was weighed until the absolute weight of the specimens was obtained. Equations (1) and (2) were applied to calculate the water desorption and absorption respectively.

\[
\text{Water desorption (\%)} = \frac{W_0 - W_t}{W_t} \times 100 \quad (1)
\]

\[
\text{Water absorption (\%)} = \frac{W_t - W_0}{W_0} \times 100 \quad (2)
\]

3. Results and Discussion

3.1 Alkali Treatment.
The single fiber test results showed that the tensile strength of untreated and treated PALFs were (109.92 ± 39.08) MPa and (378.94 ± 101.7) MPa respectively. The surface of the fiber changed from smooth to become rough surface. The tensile strength of treated PALF increases. This result agrees well with the
study conducted by Asim et al. [6]; in which PALF tensile strength increased after alkali treatment from 290.61 MPa to 432.01 MPa.

3.2 Flexural test

Figure 1 shows the flexural strength and flexural modulus of PP/Subang PALF composites versus fiber fraction. It shows that the PP/PALF40 composite has the maximum value of the flexural strength which is 3.22 MPa and flexural modulus which is 1.13 MPa than PP/PALF20 and PP/PALF30. Meanwhile, S. Dhakal et al. [8] obtained the flexural strength value of composite with 20 wt% fiber fraction was 124.61 MPa. This difference was due in the quality of PP, fiber, and composite fabrication used. Composites that used in Dhakal’s study had better fiber-matrix bonds than that use in this study, which is the most important thing in acquiring flexural strength of a composite, resulting in greater result of flexural strength. The bond between fiber and matrix is discussed in the next section. However, both Dhakal’s study and this study have a same trend; the greater the fiber content, the higher the flexural strength. This study also shows that fiber was able to enhance the composite ability to load bearing and hold the matrix to not failure. Failure matrix in composite indicated the limit to bearing the maximum load.

![Figure 1. Flexural strength and flexural modulus of PP/PALF composite versus fiber weight fraction.](image)

3.3 Water Content Test

PP has hydrophobic properties that is difficult to absorption and desorption in water. Absorption is an ability to hold water and desorption is the ability to release water from a composite. The rate of slope in water desorption is based on SNI procedure standards. Figures 2 (a) and 2 (b) prove that the fiber used for composite fabrication still has a water content. After the water desorption test was carried out to reach the absolute weight of the composite, all composites had the same desorption rate as pristine PP. The composites reached saturation state of (1.08 ± 0.52) % after 15 hours drying. Figure 2 (b) shows the composites reached saturation state after 16 hours soaking in the value of (8.83 ± 5.71) %. The graph plot in Figure 2 (b) agree with the results of a study conducted by Osman et al. [9] on polyester/kenaf composites with the same temperature. In Osman research, composites with the highest fiber content had the highest water absorption rate. In this study, the desorption and water absorption values meet the criteria of SNI fiberboard.
Figure 2. Results of (a) water desorption test, (b) water absorption test.

3.4 Optical Microscope (OM)

Figures 3 (a) – 3 (d) shows the observations of optical microscopes for flexural tested composites for all fiber fractions. Figure 3 (a) shows that the pristine PP was failed. Figures 3 (b), 3 (c), and 3 (d) show matrix failure for all composites while fiber-pull-out did not occurred. From OM observation, it was confirmed that there was a strong interface bonding between matrix-fiber. It was clear that the function of fiber in composite is as the load barrier. The results of current study were opposite to the results of Jaramillo et al [10] on PP/PALF composites that were observed by SEM. In Jaramillo study, it was showed that there was no strong bond between matrix and fiber. Fiber-pull-out was occurred because fiber was not wetted by PP. The efficiency of stress-strain on the matrix and fiber was important in holding the load.

Figure 3. Optical microscope observation at break point of (a) pristine PP, (b) PP/PALF20, (c) PP/PALF30, (d) PP/PALF40.
4. Conclusion
The tensile strength of treated PALF was increased by 244.74% compared to untreated PALF, from (109.92 ± 39.08) MPa to (378.94 ± 101.7) MPa. The flexural strength and flexural modulus values of (4.89 ± 0.37) MPa and (1.13 ± 0.42) MPa were possessed by the PP/PALF40 composites. The desorption water value was (1.08 ± 0.52) % and the composites reached saturation state after 15 hours drying. The absorption water value was (8.83 ± 5.71) % and the composites reached saturation state after 16 hours soaking. The flexural strength, desorption water and absorption water values met the Indonesian National Standard (SNI) for composite board. Optical Microscope observation showed that matrix failure occurred in all composites and confirmed that there was strong interface bonding between matrix-fiber.

5. References
[1] Venkateshwaran N, Elayaperumal A, Alavudeen A, and Thiruchitrambalam M 2011 Mater. Des. 32 7
[2] Elanchezhian C, Ramnath B. V, Ramakrishnan G, Rajendrakumar M, Naveenkumar V, and Saravanakumar M. K 2018 Material Today Proc. 5 1
[3] Mishra S 2001 Journal of Reinforced Plastics and Composites 20 04
[4] Asim M et al. 2015 Int. Journal Polymer Science 2015 6
[5] Arib R. M. N, Sapuan S. M, and Ahmad M. M. H. M 2006 Material & Design 27 391–396.
[6] Asim M, Jawaid M., Abdan K., and Ishak M. R 2016 Journal Bionic Engineering 13 3
[7] Hafizhah R., Juwono A. L, and Roseno S 2017 IOP Conf. Series: Material Science and Engineering 196 1-4
[8] Dhakal S and Gowda B. S. K 2017 Material Today Proc. 4 8
[9] E. Osman, A. Vakhgueit, I. Sbarski, S. Mutasher 2011 18th Int. Conf. Composite Materials 2 7
[10] N. Jaramillo, D. Hoyos, and J. F. Santa 2016 Ingeniería y Competitividad 162 2

Acknowledgement
This work was funded by PITTA 2018 Universitas Indonesia.