Study of Tensile Properties and Deflection Temperature of Polypropylene/Subang Pineapple Leaf Fiber Composites

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Abstract. The development of eco-friendly composites has been increasing in the past four decades because the requirement of eco-friendly materials has been increasing. Indonesia has a lot of natural fiber resources and, pineapple leaf fiber is one of those fibers. This study aimed to determine the influence of weight fraction of pineapple leaf fibers, that were grown at Subang, to the tensile properties and the deflection temperature of polypropylene/Subang pineapple leaf fiber composites. Pineapple leaf fibers were pretreated by alkalization, while polypropylene pellets, as the matrix, were extruded into sheets. Hot press method was used to fabricate the composites. The results of the tensile test and Heat Deflection Temperature (HDT) test showed that the composites that contained of 30 wt.% pineapple leaf fiber was the best composite. The values of tensile strength, modulus of elasticity and deflection temperature were (64.04 ± 3.91) MPa; (3.98 ± 0.55) GPa and (156.05 ± 1.77) °C respectively, in which increased 187.36%, 198.60%, 264.72% respectively from the pristine polypropylene. The results of the observation on the fracture surfaces showed that the failure modes were fiber breakage and matrix failure.

1. Introduction

The applications of natural fibers as reinforcement in composites are used as the automotive, home furnishings, construction and clothing [1]. Natural fibers are widely used because of its advantages, such as lighter, less damage during processing, a relatively good mechanical properties, renewability and biodegradability [2]. Natural fibers can produce lightweight composites, showed a tendency to replace glass fibers as the reinforcement of polymer-based composites [3]. The mechanical properties of polymers have many similarities in fulfilling structural functions. However, these limitations can be overcome by using natural fibers as the reinforcement of polymer composites [4]. The properties of fiber-reinforced composites depend on many factors such as the bonding between the fibers and the matrix, the fiber volume fraction, the fiber aspect ratio, fiber orientation and efficiency of load transfer at the interface [5].

Pineapple leaf fibers (PALF) derived from the leaves of the pineapple plant (Ananas comosus). The major manufacturers of pineapple plants are Thailand, Philippines, China, Brazil, Indonesia and India, a total of approximately 2.1 million acres of the world [6]. Pineapple leaves nowadays have
been wasted in most regions where pineapple plants grow, as only pineapple utilized. Indonesia is one of the major world producers of PALF [7].

In this study, the objective was to find the best weight fraction of PALF, that was grown in Subang, West Java, Indonesia, as the reinforcement of Polypropylene (PP) composite. PALF were alkalized by 5% Sodium hydroxide (NaOH) solution. PP/PALF composite was fabricated by a hot press method and the weight fractions of PALF were varied. Pristine PP was also used as a comparison. PP/PALF composite was tested with tensile test and Heat Deflection Temperature (HDT) test, then the fracture surfaces were observed by Scanning Electron Microscope (SEM).

2. Experimental

2.1 Materials

This experiment used PALF derived from a one year old pineapple plant as the reinforcement and polypropylene FY3012E from The Polyolefin Company (Singapore) Pte. Ltd as the matrix.

2.2 Alkaline Treatment

PALF were immersed in 5% NaOH solution at 25 °C for 5 hours. The PALF was then washed with distilled water until the pH became neutral and kept at room temperature for 24 hours, then dried at a temperature of 75 °C for 24 hours. Single fiber tensile test was conducted to know about the difference between tensile strength before and after alkalization.

2.3 Sample Fabrication

Polypropylene granules were modified into sheet form using a machine called an extruder at the temperature of 250 °C for 30 minutes. The fabrication process of the composites used a Collin 300P Hot Pressed machine by heating to a temperature of 190 °C for 15 minutes and then 35 barr pressure for 5 minutes, followed by cooling for 15 minutes. After the fabrication, the composite was cut to the required size of ASTM D638 type IV for tensile test and ISO 75 type II for Heat Deflection Temperature (HDT) test. The fracture surfaces of tensile tested specimens were observed using a Scanning Electron Microscope (SEM).

3. Results and Discussion

The results of the single fiber tensile test before and after alkalization were 359.96 MPa and (284.47 ± 40.66) MPa respectively. The tensile strength of PALF after alkalization was lower than that before alkalization because the lignin in PALF was dissolved. Lignin is soluble in an alkaline solution [8]. The poor fiber-matrix interface lowers tensile strength so that alkalization was an important treatment before the PALF was used as a reinforcement. The tensile strength and modulus elasticity versus the weight fractions of PALF in the composite are shown in Figure 1. It is clear that the tensile strength and modulus elasticity increase when using PALF as the reinforcement. The highest tensile strength and modulus elasticity belong to PP/PALF30% in the values of (64.04 ± 3.91) MPa and (3.98 ± 0.55) GPa respectively, which are 187.36% and 198.60% greater than pristine PP. The tensile strength and modulus elasticity of PP/PALF40% decreased by 10.99% and 16.08% respectively than those the PP/PALF30%. The excessive PALF can make the fibre acted as flaws and crazing occurred, thus creating stress concentration area which lowering the stiffness of the composites and fibres were more easily expose to environmental degradation [9].
Figure 1. Tensile strength and modulus elasticity versus PALF weight fraction.

Figure 2 displays the strain at break versus fiber weight fraction. From the figure, it can be seen that PALF lowers the strain at break of PP/PALF composite compared to pristine PP. It showed that the PP/PALF composite was more brittle than pristine PP. Strain at break of pristine PP is very high because PP is elastic.

Figure 3 presents the deflection temperature versus the weight fraction of PALF of the composites. It indicates that the addition of PALF as the reinforcement increased deflection temperature of the composite. The highest deflection temperature sample belongs to PP/PALF30% composite with the value of (156.05 ± 1.77) °C which was 264.72% greater than pristine PP. PALF had a bridging ability that could retard deformation of the PP matrix at high temperature [10].

Figures 4 (a) to (f) show the SEM images before (a, b, c) and after (d, e, f) tensile test of PP/PALF20%, PP/PALF30%, and PP/PALF40% composites. Figure 4 (a) and (c) show a few voids in the PP/PALF20% and PP/PALF40% composites. Meanwhile, in the PP/PALF30%, PALF were fully wetted by the PP and both had a strong interface bonding which can be seen in Figure 4 (b). Fiber pull-out, fiber breakage and matrix failure are observed in Figure 4 (d) to (f). In more detail, fiber pull-out can be seen in PP/PALF20%. Fiber breakage is exhibited in PP/PALF20%, PP/PALF30% and PP/PALF40% and matrix failure is observed in PP/PALF30%.

From SEM images, it is an evidence that the PP/PALF30% composites are the best sample and this result agrees well with the tensile and HDT test. PP/PALF20% composites had a poor interfacial bonding because the PP did not completely wet the PALF, so that the tensile strength was lower than PP/PALF30%. It could be proven that the interfacial bonding between the PP and PALF, voids and fiber distribution could affect the strength [11].
Figure 4. SEM images of (a)PP/PALF20%, (b)PP/PALF30%, (c)PP/PALF40 and SEM images after tensile test of (d)PP/PALF20%, (e)PP/PALF30%, (f)PP/PALF40%.

4. Conclusion
The optimum weight fraction of Subang PALF after alkalization treatment in PP/PALF composites was 30 wt.% The results of tensile and HDT tests showed that PP/PALF30% composites had the greatest tensile strength, modulus elasticity and deflection temperature with the values of (64.04 ± 3.91) MPa, (3.98 ± 0.55) GPa, and (156.05 ± 1.77) °C respectively which are 187.36%, 198.60% and 264.72% greater than pristine PP. In the PP./PALF30%, Subang PALF were fully wetted by PP and there was no void in the composites. The PP/PALF30% composites experienced matrix failure and Subang PALF breakage which was confirmed that bond between PP and Subang PALF was very strong.

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