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The Impact Resistance, Flammability, and Hardness of Polypropylene/ Unidirectional Sumberejo Kenaf Fiber Composites

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Abstract. The use of natural fibers to substitute synthetic fibers on composites has been an interest to be developed. Kenaf is a plant that abundant in Indonesia because it's adaptive and its fiber has good strength. The purpose of this study was to determine the value of impact resistance, flammability, and hardness of polypropylene/ unidirectional Sumberejo kenaf fiber composite boards in accordance with Standar Nasional Indonesia (SNI). Composites were fabricated by the variation of fiber, which were 30 wt%, 40 wt%, and 50 wt%. Pure polypropylene samples were also fabricated for comparison. The fabrication used a compression molding method. The best results were obtained from polypropylene / 50 wt% kenaf fiber composites with impact energy, flammability, and hardness values were (47.54 ± 10.7) J/ cm², (7.1 ± 5.1) mm/ minute, and (66 ± 0.8) HD respectively. Optical microscope observation on the impacted surface was a destruction of the matrix-fiber bonding and fiber breakage, in which showed the energy of impact was absorbed by kenaf fiber. The observation on the burned surface was burnt kenaf fibers and rest of PP that bonding with kenaf fiber, this indicated the kenaf fiber acted as an oxygen barrier.

Keywords: unidirectional kenaf fiber, polypropylene, composite, impact resistance, flammability, hardness, fiber breakage

1. Introduction

The development of the use of natural fibers to substitute synthetic fibers on fiber reinforced composites has been an interest to the researchers. As a tropical country, Indonesia is a fertile land for various types of plants such as pineapple, bamboo, kenaf where those plant fibers can be used as a substitute for glass fiber [1]. The advantages of using natural fibers were eco-friendly, abundant of its availability, and relatively cheap [2].

The hydrophilic on natural fibers and the hydrophobic on polymers that act as the matrix decreased the bond strength between matrices and fibers [3]. Beside that, the bonds are influenced by several basic factors, including fiber roughness topology, type, and model of fiber fracture and adhesion between matrix surfaces and fibers [4]. To increase this bond, lignin and hemicellulose on natural fibers should be reduced by giving the alkaline treatment to the fiber which the best concentration was 5% for kenaf fiber (KF) [5, 6]. The fiber tensile strength was related to the mechanical strength of composites. Asim (2016) reported that the alkaline treatment increased the fiber tensile strength 161% from 282.60 MPa to 455.74 MPa after the treatment [3].



The impact resistance of recycled polypropylene (PP)/ chopped kenaf fiber composites reported that the 20 % weight fraction of KF increase 15 % the impact resistance than the recycled PP itself [7]. Pornwannachai (2018) studied flax/ PP composites and it showed that the flammability test result was (19.3 ± 1.3) mm/ minute with the random fiber oriented [8]. The effect of natural fiber reinforced composite to the hardness test reported by Lusiani (2015), that the longer fiber length increase the hardness of composites [9]. The fiber length and its oriented were the main factors of composites mechanical strength [10].

Previously study showed the weight fraction of 40 wt% Sumberejo kenaf fiber on PP/ SKF composites obtained the best tensile strength and temperature deflection [11]. This study was about to study the continuous unidirectional fiber oriented on the composites. Impact resistance, flammability, and hardness properties of PP/Sumberejo Kenaf fiber (SKF) composites have not been studied. Therefore, in this study the impact resistance, flammability, and hardness of PP/ SKF composites with fiber fractions of 30 wt%, 40 wt%, and 50 wt% of unidirectional orientation fiber were reported.

2. Materials and Methods

2.1 Materials and Fabrication

Kenaf fiber was obtained from Sumberejo, Central Java, Indonesia, and the matrix was BI32AN PP pellet from PT Chandra Asri Petrochemical. For alkaline treatment, NaOH was used from PT Merck. Kenaf fiber was cut into a length of the composite mold, then it was soaked in 5 % NaOH solution at room temperature for 24 hours. After 24 hours, the fiber was washed with aqua bidest for 5-7 times until the washed-water was colorless. Then, it was dried at room temperature for 40 hours and followed at 60 °C for 24 hours. The single fiber test was carried out for raw SKF and treated SKF. SNI 08-1112-1989 was applied for the standard procedure in which the fiber as a bunch length of 5 cm and width of 0,5 cm for five specimens at room temperature.

PP pellet was fabricated into sheets in a mold (20 cm x 30 cm) by compression molding method with a thickness of 1 mm. The temperature of compression molding was 190 °C for 10 minutes. The fiber fractions of 30 wt%, 40 wt%, and 50 wt% were prepared for unidirectional fiber oriented and arranged in between PP sheets. The fabrication of composites used compression molding method then fabricated with a pressure of 0 MPa for 10 minutes and 5 MPa for the next 10 minutes at the temperature of 190 °C, followed by cold press method for 15 minutes on the room temperature. The samples were identified as PP, PP/30SKF, PP/40SKF, and PP/50SKF.

2.2 Sample Testings and Microscope Observation

The samples of impact resistance test were prepared according to ASTM D6110-10 standard for Charpy method with the dimension of 60 mm x 10 mm and a thickness of 4 mm. A notch of 2 mm thickness with an angle of 45° was created as required by the standard. This test was carried out on a GT-7045 Gotech Testing Machine. Before and after impact tested samples were observed by optical microscope using a Zeiss Axiocam microscope camera.

The standard procedure for flammability test was UL94 Horizontal Burning from The UL Thermoplastics Testing Center. The dimension of the specimen was 125 mm x 13 mm with a thickness of 4 mm. The measurement was counted on the time whe the flame burning on the specimen length of 75 mm or until the flame stopped before it reached the length. The test was carried out on a flammability tester. For the comparison, the flamed samples were observed by the microscope.

ASTM D2240 standard was used for hardness test on a Krisbow Durometer shore D from Krisbow. Ten specimens were prepared for this test. The minimum thickness according to the standard is 60 mm and to reach it can pile several specimens.

3. Result and Discussion

3.1 The Single-Fiber Test

The tensile strengths of kenaf fiber before and after alkaline treatment were 83.57 MPa and 186.18 MPa respectively. The treatment made the fiber stronger by 123 % after the lignin and hemicellulose

were removed from the fiber. This result agreed well with the previous result of Asim (2016) which the value KF fiber tensile strength increased 123 % after alkaline treatment [3].

3.2 The Impact Resistance Test, Flammability test, and Hardness test

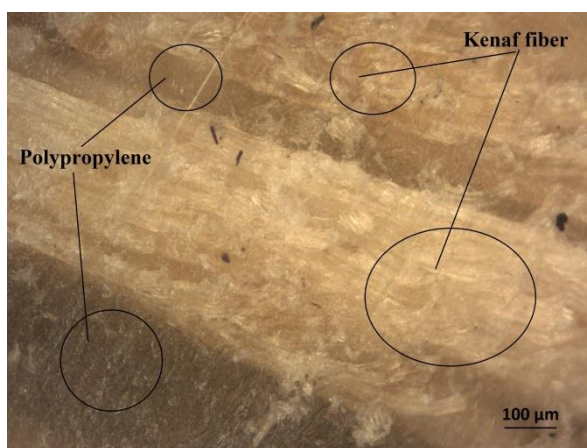
Table 1 shows the result of impact resistance, flammability, and hardness tests. The PP/ 50SKF composites had the best composites. The continuous unidirectional SKF affected the impact resistance because the continuous fiber acted as an energy impact absorber. In flammability test, the SKF acted as an oxygen barrier which made the flame inconvenienced to reach the deepest part of composites. In hardness test, the fiber withstood the load of Durometer sensor. The result of impact resistance test similar to Suharty (2016) with the addition KF to PP made the composites 15% more resist the energy impact [7]. Values of flammability test similar to Pornwannachai (2018) research of natural fiber as flame resistant [8]. While hardness values agreed well to Lusiani (2015) which more longer length of natural fiber made higher hardness values of composites [9].

Table 1. The results of the impact resistance, the flammability, and the hardness tests

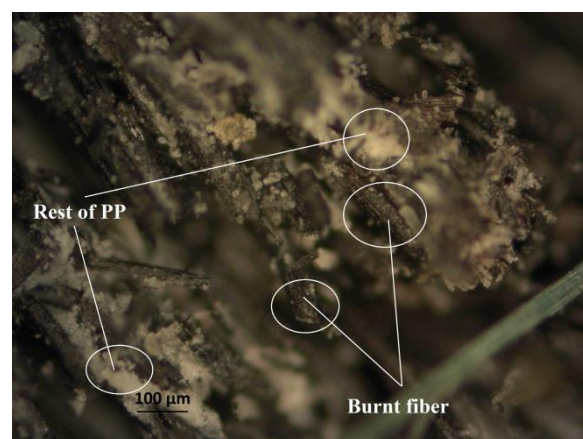
	Impact resistance (J/cm ²)	Flammability (mm/minute)	Hardness (HD)
PP	7.17	25	40.2
PP/30SKF	24.86	13.6	58.1
PP/40SKF	32.6	12.2	61.1
PP/50SKF	47.54	7.1	66

3.3 Optical Microscope Observation specimen

Figure 1 shows the optical microscope observation for PP/ 50SKF before and after flammability (a, b) and impact resistance (c, d) tests. The after flammability test sample shows the burned polypropylene and stacked on fiber's surface. The fiber acted as an oxygen barrier in which the oxygen was needed for the burning. The after impact resistance test sample shows fiber breakage occurred as a proof that the fiber absorbed the impact energy. From this observation, it showed that the continuous unidirectional fiber played important roles as energy absorber and oxygen barrier.



(a)



(b)

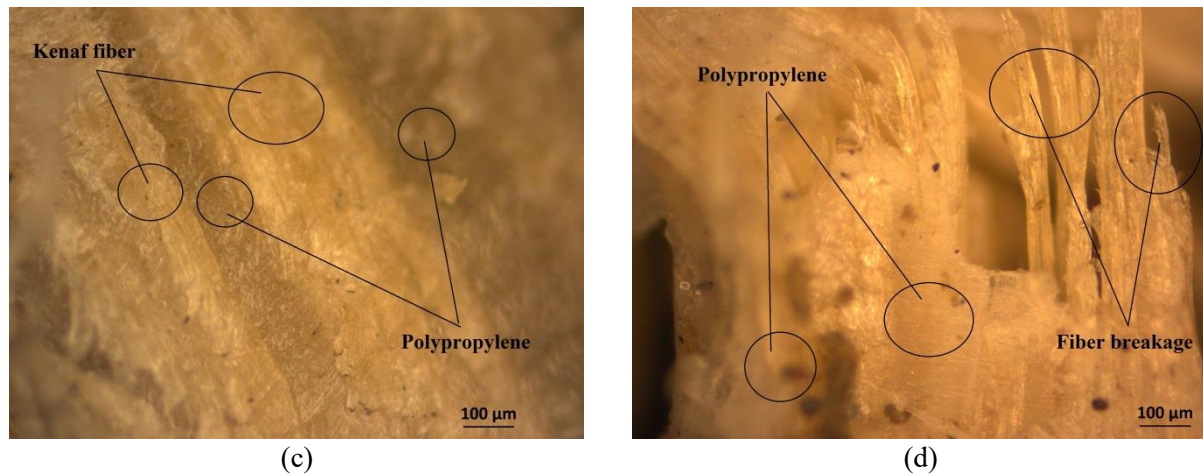


Figure. 1 Optical microscope observation of PP/50SKF surface samples. (a) before flammability test (b) after flammability test (c) before impact resistance test (d) after impact resistance test.

4. Conclusion

Alkaline treatment was proven to increase the tensile strength of SKF by 123% higher than kenaf fiber before alkaline treatment. The addition of SKF made the ability to impact resistance, flammability, and hardness increased. The PP/50wt% SKF composites had the highest energy impact of $(47.54 \pm 10.7) \text{ J/cm}^2$, the lowest flame rate of $(7.1 \pm 5.1) \text{ mm/minute}$ and highest hardness value of $(66 \pm 0.8) \text{ HD}$. The continuous unidirectional SKF acted as an oxygen barrier and impact energy absorber.

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