Tensile Properties and Deflection Temperature of Polypropylene/Sumberejo Kenaf Fiber Composites with Fiber Content Variation

S.L. Ollivia¹, A.L. Juwono¹ and Seto Roseno²

¹Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Indonesia, Depok 16424, Indonesia
²Agency for Assessment and Application of Technology, Serpong 16340, Indonesia

E-mail: ariadne.laksmiteri@ui.ac.id

Abstract. The use of synthetic fibers as reinforcement in composites has disadvantage which are unsustainable and an adverse impact on the environment. An alternative reinforcement for composites is natural fiber. Polypropylene and Sumberejo kenaf fibers were used respectively as the matrix and reinforcement. The aim of this research was to obtain the optimum tensile properties and deflection temperature with the variation of kenaf fiber fractions. Polypropylene/kenaf fiber composites were fabricated by hot press method. The kenaf fiber was soaked in NaOH solution before being used as the reinforcement and polypropylene was extruded before being used as the matrix. The weight fractions were varied to produce composites and pristine polypropylene samples were also prepared for comparison. The optimum tensile strength, modulus and deflection temperature were found in the composites with the 40 wt% kenaf fiber fraction with an increase up to 80% and 170% compared to the pristine polypropylene with the values of (60.3 ± 4.3) MPa and (159.1 ± 1.8) °C respectively. The Scanning Electron Microscope observation results in the fracture surface of the composites with the 40 wt% fiber fraction showed a relatively good bonding interface between fibers and the matrix and the failure modes were fiber breakage and matrix failures.

1. Introduction

Synthetic fibers have been used in industry but these materials are not environmentally friendly and appear to be environmental issues such as waste disposal and pollution from combustion [1]. The use of natural fibers as reinforcement in composites have been widely researched and developed in recent years. Utilization of natural fibers has increased due to the relatively low cost of materials, high specific modulus, relatively light compared to glass fiber, lower energy requirements, the availability of abundant, biodegradable, resistance to deforestation and other benefits [2]. Natural fibers are expected to be an alternative to synthetic fibers and give good impact to the environment [3]. Automotive and aircraft industry requires a renewable and environmentally friendly materials [4]. Types of natural fibers used in the automotive industry is hemp, sisal, wool and kenaf. Kenaf fiber began to be developed in the world such as BMW, Toyota, and Ford as a package tray and door panels in the car [5]. Not only in the automotive field, kenaf fiber is also used in textile, agriculture, medicine and other fields. In an effort to save the forest wood, kenaf fibers along the stem has been developed for the manufacture of good quality pulp [6]. Indonesia is a tropical country with a variety of natural resources that have the potential to develop natural fibers such as jute, flax, cotton, abaca, agave, linum, roselle and kenaf [7]. Kenaf plant has many benefits because it can be cultivated using a simple technology, the relatively short lifespan of about 4-5 months [8].

The content of fiber determines the mechanical properties, thermal properties and morphology of the composite [3]. Lee et al. [9] have done research on long and discontinuous kenaf fiber reinforced polypropylene composites, it was concluded that the kenaf fiber reinforced PP composites have an optimum nominal fiber fraction of 30% by weight at which the tensile and flexural modulus are the highest, while the reduction in strength is minimal. Zampaloni et al [10] reported that chopped kenaf fiber content of both 30% and 40% by weight has been proven to provide adequate reinforcement to increase the strength of the...
polypropylene powder. In the research by Wambua et al [11], the best results of tensile strength lies in composites with a weight fraction of 50 wt% using randomly fibers oriented. Bledzki et al [12] conducted a research on a composite with some natural fiber reinforcement, including kenaf fibers. Weight fraction of the fiber used in this research was 40 wt% with a size of 2 mm kenaf fiber.

Natural fibers require alkali treatment prior to be used as reinforcement in composites. Alkali treatment on fiber is the fiber immersion in a solution of NaOH. Alkali treatment on natural fibers can increase the stiffness, strength, modulus of dynamic flexibility in the composite, and improve the interface bond strength and adhesion between matrix and fiber. Alkali content used was 5% because provides the optimal tensile strength kenaf fiber reinforced polypropylene composite [13].

In this research kenaf fiber derived from Sumberejo, East Java, Indonesia was used as the reinforcement for polypropylene, so that it can provide added value in its use. Continuous oriented of kenaf fiber used in this research to aim obtaining the optimal mechanical properties and thermal properties.

2. Experimental Method

Preparation of Materials. The materials used in this research were kenaf fibers (KF), polypropylene (PP), and NaOH flakes. The 5% NaOH solution was prepared by mixing aquabidestilation with NaOH flakes with a ratio of 1:20. The kenaf fibers were soaked for 24 hours and then rinsed with destilated water. The fiber was dried at room temperature for 48 hours and dried at the temperature of 60 °C for 24 hours. Polypropylene pellets were extruded to make sheet forms of polypropylene so that the PP easily dispersed and wetted the KF.

Fabrication of Composite. KF and PP in sheet form were arranged according to a certain weight fraction. Weight fraction of KF in PP used were 20 wt% (PP/Kenaf20), 30 wt% (PP/Kenaf30), 40 wt% (PP/Kenaf40), 50 wt% (PP/Kenaf50) and 60 wt% (PP/Kenaf60). KF and PP were weighed then arranged into a mold in the form of lamina. KF and PP then hot press conducted at 190 °C for 5 min at a pressure of 50 Bar. The composites for tensile test specimen prepared according to the ASTM D638 type IV standard. The specimens for heat deflection temperature test were cut according to standard of ISO 75-2.

3. Result and Discussion

Single fiber tensile test results of kenaf before alkalization treatment is amount to 215.9 MPa and after alkalization treatment is amount to 111.5 MPa. Figure 1 shows a tensile strength value of each weight fraction of fiber. For pristine PP has a value of tensile strength of 32.7 MPa, values for tensile strength of the composite increased when adding fiber weight fraction of up to 40 wt%. The maximum tensile strength value obtained on a sample of PP/ Kenaf40. The increased value of tensile strength due to the greater fiber content will strengthen the composite, but after passing through the fiber fraction of 40 wt%, the value of tensile strength decreased due to the PP/Kenaf50 and PP/Kenaf60 because there are many fiber content so that PP difficult to wetting the fibers. Young modulus increase up to the optimum ratio of weight fraction in the sample PP/Kenaf40 and then decreased in PP/Kenaf50, as can be seen in Figure 1. Young modulus of pristine PP is 1.8 GPa, PP/Kenaf40 has a modulus of young of 6.4 GPa.

Lee et al have done research on long discontinuous kenaf fiber [9]. From this research, the value of the tensile strength of pristine PP amounted to (33 ± 2) MPa with a maximum tensile strength value in the composite with a weight fraction of 40 wt%. According to Lee et al, the value of tensile strength increasing due to interaction of the interface adhesion to the matrix and fibers. The interaction is a physical, because the composite fabrication process does not use the coupling agent. The use of coupling agent indicate a chemical changes. During a tensile test, interface bonding between matrix and fiber is not strong enough to resist the load and it causes the lower load transfer and obtained a fracture. Composite parts that are not filled with fibers may be another cause of low tensile strength because the void is a source of stress.

Figure 2 shows the deflection temperature of the weight fraction of fibers in composite samples of pristine PP. The pristine PP has a deflection temperature of 59 °C, the addition of fiber to 40 wt% in the samples of PP/Kenaf40 lead to higher deflection temperature composite became 159.1 °C; the sample of PP/Kenaf50 obtained a deflection temperature amounted to and the PP/Kenaf60 has a deflection temperature amounted to 94.2 °C. The values obtained with optimum deflection temperature is the weight fraction of fiber composites with 40 wt%. Bledzki et al have done research on the effect of heat on a composite polypropylene/kenaf fiber [14]. A significant increase in temperature with increasing weight fraction of fiber. Bledzki assume that the parameters Heat deflection Temperature is affected by two things: the load on the fiber and matrix interface strength. The difference value Heat Deflection Temperature test results are also affected by the weight fraction in the composite.
Figure 1. Tensile strength and young modulus of PP/KF composites versus fiber fractions.

Figure 2. Deflection temperature of PP/KF composites versus fiber weight fractions.

Figure 3 shows the Scanning Electron Microscope (SEM) images of sample PP/Kenaf20, PP/Kenaf30, PP/Kenaf40 and PP/Kenaf50 before and after the tensile test. In the sample of PP/Kenaf20 (Figure 3 (a)) before the tensile test shows voids and not homogeneous layer between matrix and fibers, it can affect the mechanical and thermal properties of composites. Figure 3 (b) shows the SEM images of PP/Kenaf20 after the tensile test, it shows there are fibers pull-out from matrix. In Figure 3 (c) shows the SEM images before tensile tests on composites PP/Kenaf30, it shows the layer between fiber and matrix is homogeneous. In Figure 3 (d) there are a failure modes in the form of fiber pull-out from the matrix and fiber breakage. SEM image before tensile test on a sample of PP/Kenaf40 (Figure 3 (e)) shows the number of relatively less voids and layers between the matrix and fiber are more homogeneous than samples PP/Kenaf20. Figure 3 (f) shows the SEM images a sample of PP/Kenaf40 after the tensile test which shows that less fibers pull-out than the PP/Kenaf20 and PP/Kenaf30. SEM image before tensile test on a sample of PP/Kenaf40 (Figure 3 (e)) shows the number of relatively less voids and layers between the matrix and fiber are more homogeneous than samples PP/Kenaf20. Figure 3 (f) shows the SEM images a sample of PP/Kenaf40 after the tensile test with a magnification of 50 times which shows that less fibers pull-out than the other samples. Figure 3 (g),(h) show the SEM images of PP/Kenaf50 before and after tensile test. There are voids and fiber failure such as fiber breakage and fiber is not completely equitable distribution. Figure 4 shows the fiber is not completely wetted and separated between the matrix and fibers relatively much in amount than the other samples. Samples PP / Kenaf60 value less than the tensile strength of the composite pristine PP and the other PP/kenaf fiber, this is due to the failure mode of this fiber composition is larger in amount than the other samples.
Surface bond between the matrix and fibers determines the mechanical properties of the composite. The load is transferred from the matrix to the fibers through the interface, the interface bonding which is required to reach the optimal reinforcement, natural fiber has hydrophilic properties and matrix has hydrophobic properties so that cause a not good interface bonding as to restrict the mechanical strength of the composite. The bond formed between the matrix and the fiber matrix can be influenced by the ability of wetting the fibers. The fibers are not wetted properly will result in defects on the bonding interface so can obtain stress on the composite [15].

**Figure 3.** SEM image of PP/KF. (a) PP/Kenaf20 before tensile test (b) PP/Kenaf20 after tensile test (c) PP/Kenaf30 before tensile test (d) PP/Kenaf30 after tensile test (e) PP/Kenaf40 before tensile test (f) PP/Kenaf40 after tensile test (g) PP/Kenaf50 before tensile test (h) PP/Kenaf50 after tensile test.
Figure 4. Sample of PP/Kenaf60 after tensile test.

4. Conclusion

From the tensile test and Heat deflection Temperature test for pristine PP and composites of PP/kenaf fiber obtained results of tensile strength and deflection temperature which increases with fiber addition in the composite up to 40 wt% fiber fraction, then the value of tensile strength and deflection temperature decreased after addition of the 50 wt% and 60 wt% fibers content. The highest value for tensile strength and deflection temperature are in composite with weight fraction of 40 wt% which is amounted to (60.3 ± 4.3) MPa and (159.1 ± 1.8) °C respectively, these values increase each 80 % and 170% when compared to polypropylene. This is also supported by observations of Scanning Electron Microscope which showed the good interface bonding between matrix and fiber in sample PP/Kenaf40.

Acknowledgment

This work was funded by Universitas Indonesia for PITTA grant in 2016

References

[1] Haameem M J A, Abdul Majid M S, Afendi M, Marzuki H F A, Fahmi I. and Gibson A G 2016 Compos. Struct. 136 1
[2] Saba N, Faridah M T and Jawaid M 2015 Constr. Build. Mater. 76 87
[3] Pickering K L, Efendy M G A and Le T M 2016 Compos. Part A Appl. Sci. Manuf. 83 98
[4] Szolnoki B, Bocz K, Zóti P L, Bodzay B, Zimonyi E, Toldy A, Morlin B, Bujnowicz K, Władyka-Przybylak M and Marosi G 2015 Polym. Degrad. Stab. 119 68
[5] John M J, Bellmann C and Anandjiwala R D 2010 Carbohydr. Polym. 82 549
[6] Marjani, Sudjindro, Purwati R D 2009 Jurnal Littri vol. 15. 2 53
[7] Sudjindro 2011 Perspektif 10 92
[8] Singh R K, Dubey S R and Srivastava R K 2013 Global Journal of Biology, Agriculture & Health Sciences 2 72
[9] Lee B H, Kim H J and Yu W R 2009 Fibers Polym. 10 83
[10] Zampaloni M, Pourboghrat F, Yankovich S A, Rodgers B N, Moore J, Drzal L T, Mohanty A K and Misra M 2007 Compos. Part A Appl. Sci. Manuf. 38 1569
[11] Wambua P, Ivens J and Verpoest I 2003 Composites Science and Technology, 63 1259
[12] Bledzki A K and Gassan J 1999 Prog. Polym. Sci. 24 221
[13] Asumani O M L, Reid R G and Paskaramoorthy R. 2012 Compos. Part A Appl. Sci. Manuf. 43 1431
[14] Bledzki A K, Franciszczak P, Osman Z, and Elbadawi M 2015 Ind. Crops Prod. 70 91
[15] Liu W, Drzal L T, Mohanty A K and Misra M 2007 Compos. Part B Eng. 38 352