Jurnal
Teknologi

Full Paper

TENSILE PROPERTIES OF UNIDIRECTIONAL KENAF FIBER POLYPROPYLENE COMPOSITE

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Article history
Received
18 December 2015
Received in revised form
10 March 2016
Accepted
25 April 2016

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(A) WATER RETTING


(B) KENAF FIBERS


(C) TENSILE TEST

Abstract

Over the last decade, awareness of environmental issues and the shortage of petroleum resources contribute to the important factors that encourage researchers to explore the potential use of natural fibers such as kenaf as reinforcement in fiber reinforced composites. The objective of this study was to investigate the effect of different processing condition (temperature, pressure and pressing time) on the tensile properties of unidirectional kenaf fiber polypropylene composite. Samples of composites were prepared by a hot pressing method. In this work, kenaf continuous long fibers from water retting process at 40%wt were aligned in parallel. Polypropylene (PP) in the form of pellets and powder had been used as a matrix. The results showed that, samples produced at temperature 210^{0}C and pressure 5 MPa for 6 minutes hot pressing gives excellent tensile properties which 262% of improvement as compared to pure PP. This indicates that, kenaf fiber is suitable as reinforcement in polymer composite.

Keywords: Natural fiber; thermoplastic polymer; mechanical properties; unidirectional

Abstrak

Sejak beberapa dekad yang lalu, kesedaran mengenai isu alam sekitar dan kekurangan sumber petroleum menyumbang kepada faktor penting yang mendorong penyelidik untuk meneroka potensi penggunaan gentian asli seperti kenaf sebagai penguat dalam komposit diperkuat gentian. Objektif kajian adalah mengkaji kesan keadaan pemprosesan berbeza (suhu, tekanan, masa penekanan) ke atas sifat regangan komposit searah gentian kenaf polipropelina. Sampel komposit dihasilkan menggunakan kaedah penekanan panas. Bagi kajian ini, gentian kenaf panjang berterusan daripada proses pengeretan air pada 40% berat telah disusun secara selari. Polipropelina (PP) dalam bentuk pallet dan serbuk telah digunakan sebagai matrik. Keputusan menunjukkan bahawa, sampel yang dihasilkan pada suhu 210^{0}C dan tekanan 5 MPa untuk proses penekanan selama 6 minit memberikan sifat regangan yang sangat baik di mana peningkatan sebanyak 262% penambahbaikan berbanding PP tulen. Ini menunjukkan bahawa, gentian kenaf sesuai digunakan sebagai penguat dalam polimer komposit.

Kata kunci : Gentian asli; polimer termoplastik; sifat mekanikal; searah

1.0 INTRODUCTION

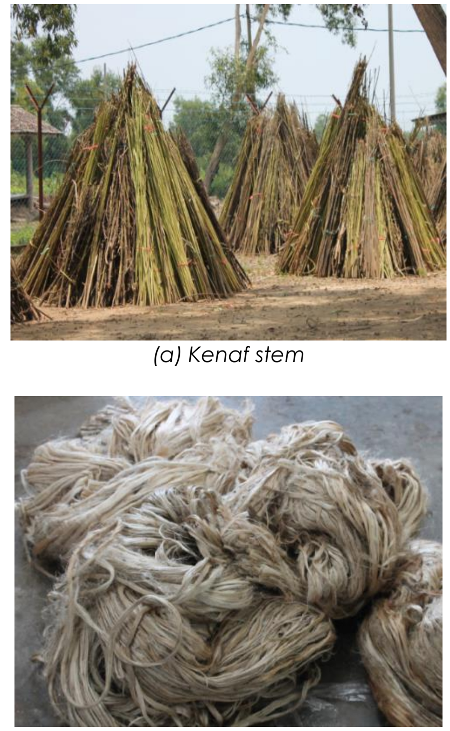
Synthetic fibers are widely used to reinforce polymeric resins in fabrication of composite materials due to its excellent mechanical properties. Composite from synthetic fibers offer higher strength-to-weight ratio makes it specifically suitable to be used in the automotive sector [1]. However, this synthetic fiber such as glass, aramid and carbon fibers are expensive and often lead to environmental and recycling issues [2]. Natural fibers which are well known to be less expensive, renewable, environmentally friendly with undoubtedly outstanding mechanical and physical properties are the best solution to replace synthetic fibers in market. Besides, it poses no risk to human health when the particle is inhaled as well as biodegradable. Combination of low cost, light weight, high strength and stiffness makes natural fibers widely used in production of lightweight composites. These natural fiber composites have potential application in automotive parts such as door panels, seat covering and floor panels. The use of natural fibers in automotive parts adopted since 1940 by Henry Ford followed by Mercedes-Benz in 1990 which applied composites for interior parts produced from natural fibers and polypropylene.

Several factors that may affect the mechanical properties of fiber reinforce composite are fiber length, loading and its orientation in the matriks. Several works on fiber reinforced composites have showed very high stiffness and strength of fibers oriented in one direction or unidirectional. Ochi [3], reported that unidirectional kenaf fiber reinforced PLA (Poly-lactic acid) composites at a fiber content of 70% have high tensile and flexural strength at 223 MPa and 254 MPa respectively. Lee et al. [4] found that, tensile stress of laminated composites fabricated with unidirectional kenaf fiber orientation with polypropylene film was about 2–4 times higher than those with the randomly oriented samples. Van de Velde & Kiekens[5] on the other hand suggested that unidirectional of boiled flax combine with MAA-PP has the best mechanical properties when compared to multidirectional flax/polypropylene.

This paper investigates the mechanical properties of unidirectional continuous long kenaf fiber reinforced with polypropylene (PP) sheets and powders. The effects of processing parameters on tensile properties of the composite were discussed.

2.0 MATERIALS

Continuous long fibers of kenaf from bast approximately 1.5 meters height were supplied locally by Lembaga Kenaf Dan Tembakau Negara (LKTN), Kelantan. Kenaf bast fibers have undergone water retting process in order to produce the long fibers as shown in Figure 1. The mechanical and physical properties of these kenaf fibers are listed in Table 1.



(a) Kenaf stem

(b) Continuous long kenaf fiber

Figure 1 Kenaf fibers

Table 1 Typical properties of kenaf fiber

Kenaf fiber	
Properties	**Details**
Young's modulus (MPa)	4300
Tensile strength (MPa)	250
Density (g/cm³)	1.4
Fiber diameter (μm)	81
Fiber length (mm)	60

PP was supplied by Lotte Chemical Titan (M) Sdn. Bhd., Pasir Gudang, Johor, Malaysia. Material properties supplied by the manufacturer can be found in Table 2. While, the properties of PP powder that supplied by Goonvean Fibres Ltd., United Kingdom with particle size maximum 90μm can be found in Table 3. PP powder is used as a polymer that mixed uniformly with kenaf fibers. PP powder will easier to spread between the kenaf fibers compared to PP pellets [6].

Table 2 Typical properties of PP pellet

Property (TITANPRO PX617)	
Properties	**Details**
Melt Flow Rate, at 230⁰C	1.7 g/10 min
Density	0.9 g/cm³
Tensile Strength at Yield	350 kg/cm²
Elongation at Yield (%)	9
Flexural Modulus	16500 kg/cm3
Notched Izod Impact Strength at 23⁰C	6 kg.cm/cm
Water absorption after 24 hours (%)	0.02

Table 3 Properties of PP powder

Polypropylene Powder (HM20/70P)	
Properties	**Details**
Product format	Fine powder
Appearance	White powder
Particle size	Max: 90µm (>95%) Average(>50%): ~55-75µm
Typical moisture content (%)	0.0-0.1
Melting point (^{0}C)	159-171
Density (g/cm3)	0.90-0.91
Biodegradability	Non-biodegradability
Melt flow index (g/10min) [230°C, 2.16kg]	23-59

3.0 COMPOSITES PREPARATION

Composite samples were prepared using the hot pressing method where a simple flat sample was fabricated using a mold consist of two plates. A pressing process occurs when all the fibers and matrix were pressed together while the heat and pressure applied for a certain time. Table 2 shows the processing parameter for the fabricated samples. The methodology for the whole process is shown in Figure 2. Composites preparation involves two steps, the preparation of two sheets using PP pellet followed by fabrication of composites by sandwiching the kenaf long fibers with the PP powder between the two layers of PP sheets.

The kenaf bast fibers were combed to produce long, clean and untangle the strong bonding of individual fibers [7]. This process is also to ensure that the fibers are relatively parallel. Then, the fibers were stored in an oven at temperature of 40^{0}C for 24 hours to remove moisture prior to pressing process.

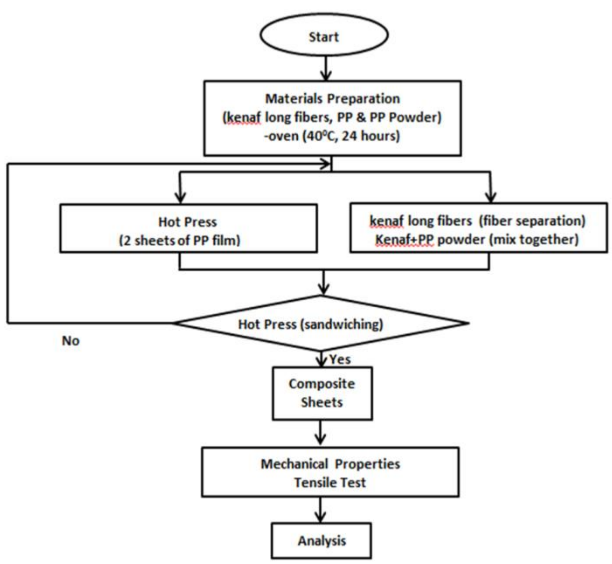


Figure 2 Methodology process

A pellet type of PP matrix was used and converted into films by a hot pressing with the processing temperature and pressure that designated on Table 4. For this process the pressing time is set for 5 minutes. Meanwhile, PP powders are sprinkled on kenaf fibers and mixed together in the container until all the powders uniformly distributed between the kenaf fibers. Lastly, kenaf fibers with PP powder were sandwiching together between the two layers of PP sheets as shown in Figure 3 and continued with the pressing process with processing parameter as shown in Table 4.

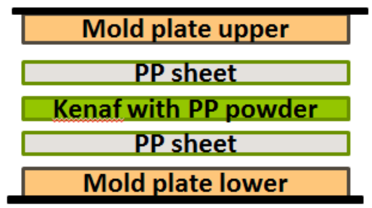


Figure 3 Schematic diagrams of the materials sandwiching

Figure 4 shows the kenaf fiber after combed, PP powder and the PP pellets that used in this study.

(a) Kenaf fibers after combed

(b) PP powder

(c) PP pellet

Figure 4 Materials

The quantity of polypropylene powder was calculated to achieve the desired fiber content for each composite. The kenaf fiber content is fixed at 40% by weight. The processing parameters are presented in Table 2.

Table 4 Processing Parameters

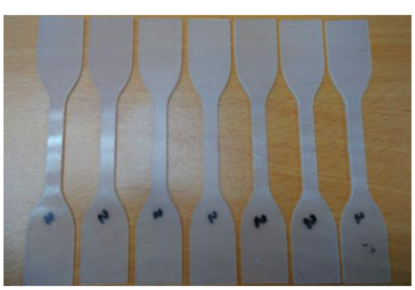
Temperature (^0C)	Pressure (MPa)	Pressing Time (minutes)
190	5	2
190	10	2
190	5	6
190	10	6
210	5	2
210	10	2
210	5	6
210	10	6

4.0 RESULTS AND DISCUSSION

Tensile testing was done according to ASTM D638 by using an Instron universal testing machine (Model 3366) with the crosshead speed was set at 5mm/min. The samples of PP/ unidirectional kenaf composite are shown in Figure 4(a) and pure PP fabricated from PP pellets in Figure 4(b). From the testing, results of tensile strength and tensile modulus were measured. Five samples from each parameter were used in this study.

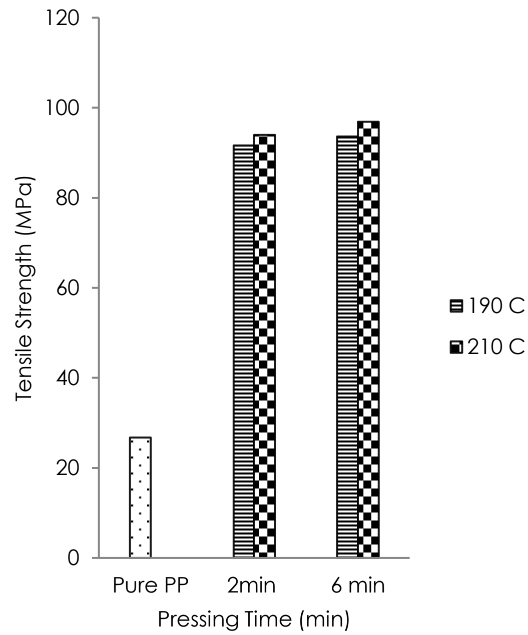
The results of tensile strength at pressure 5 MPa and 10 MPa are shown in Figure 5. It can be seen that the tensile strength depends strongly on the long kenaf fiber which have higher tensile compared to pure PP. This can be seen through a study conducted by Lee et al. [4] determined that tensile strength will increase 300% with 40%wt kenaf added in unidirectional orientation compared to pure PP.

(a) *PP/unidirectional kenaf composite*

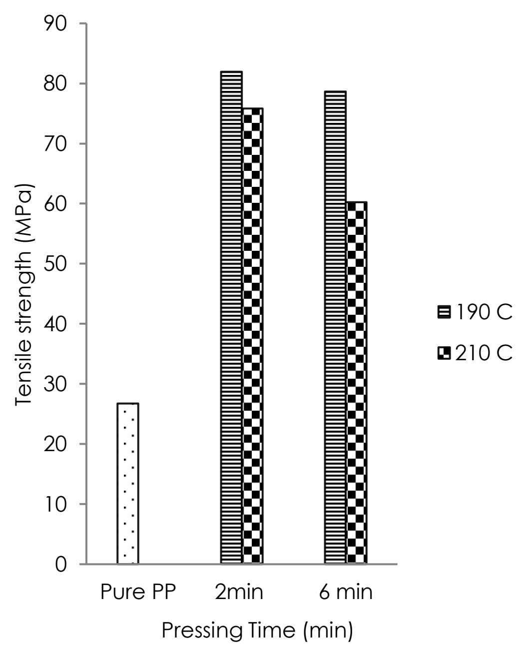


(b) *Pure PP*

Figure 5 Samples



(a) Tensile strength at pressure 5 MPa

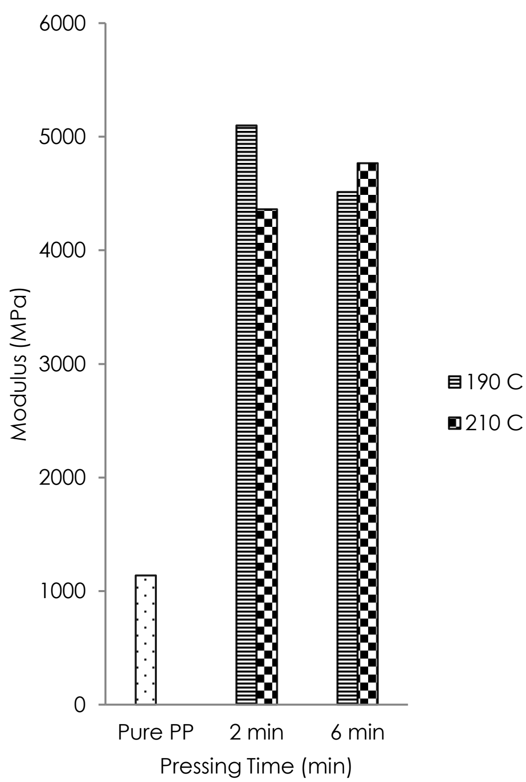


(b) Tensile strength at pressure10 MPa

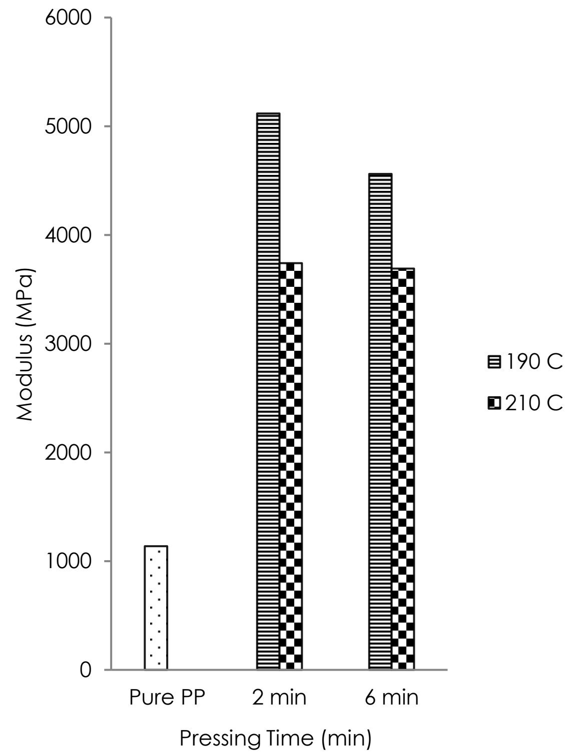
Figure 6 Tensile strength

Figure 5 (a) shows at processing pressure 5 MPa, tensile strength slightly increased proportional to the temperature and pressing time. It can be suggested that the impregnation of PP into kenaf fibers increased and favorable at 210^{0}C pressing temperature. This is due to higher viscosity of PP at 190^{0}C which require high temperature for fiber impregnation. On the other hand as shown in Figure 5(b), at processing pressure 10 MPa, the tensile strength decreased proportional to the temperature and pressing time. The exposure to the high temperature for a certain period of time with high pressure causes the quantity of PP overflowed from the mold and thermal decomposition of kenaf fiber [8]. The lack of matrix will also result in strength decrease. This proves that, pressing conditions, including pressing temperature, pressure and time affect the tensile properties.

Figure 6 represent the graph of young modulus at pressure 5 MPa and 10 MPa respectively. The findings show that, young modulus decreased with the increased of temperature and pressing time except for sample of 6 minutes pressing time at pressure 5 MPa. The young modulus may also be influenced by the long kenaf fibers which have higher modulus compared to pure PP [9].



(a) Young Modulus at Pressure 5 MPa



(b)*Young Modulus at Pressure 10 MPa*

Figure 7 Young Modulus

5.0 CONCLUSIONS

As a conclusion of this study, kenaf fiber has suitable properties to be used in engineering as fiber reinforced polymer composite especially in automotive sector. The result shows that, tensile modulus and the tensile strength were higher for the unidirectional kenaf polypropylene composite compared to pure PP with 319% and 262% improvement respectively. These reveal that the incorporation of kenaf fiber into the matrix is effective for reinforcement besides the unidirectional fiber orientation. Furthermore, it is also proven that there is a good stress transfer from the PP matrix to the incorporated kenaf fiber. From the study, sample produced at the temperature 210^{0}C and pressure 5 MPa for 6 minutes hot pressed gives an excellent tensile strength which is 262% improvement compared to sample without incorporation of fiber and other processing parameters. For the future work, fiber modification and use of coupling agent are recommended to further improve the mechanical properties of composite.

Acknowledgment

Authors acknowledge Ministry of Education Malaysia for sponsoring this work through LRGS/TD/2012/USM-UKM/PT/05 and Ministry of Higher Education Malaysia for granting the scholarship.

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