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Influence of Kenaf (KNF) Loading on Processing Torque and Water Absorption Properties of KNF-Filled Linear Low-Density Polyethylene/Poly (vinyl alcohol) (LLDPE/PVA) Composites

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Abstract

The KNF-filled linear low-density polyethylene composites were prepared by using an internal mixer (Thermo Haake Polydrive) at 150°C and 50 rpm rotor speed. The composites were mixed with different KNF loading, i.e., 10, 20, 30 and 40 phr. The effects of KNF loading on processing torque and water absorption of the composites were investigated. The results indicated that stabilization torque and water absorption were increased with increasing KNF loading. Composites with higher KNF loading demonstrate higher equilibrium water absorption.

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1. Introduction

The utilization of natural fibers (i.e., kenaf, hemp, jute, etc.) as reinforcement or fillers in polymer has been widely explored in the last few years[1,2]. Kenaf fibers have found advantageous due to its short plantation cycle,

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environmental friendly and being inexpensive[3,4]. A few researchers claimed that mechanical properties of kenaf thermoplastic polyurethane has resulted in best tensile and flexural strength of kenaf reinforced thermoplastic polyurethane composites as reported by[6]. In order to expand the usage of natural fiber polymer composites, it is important to investigate their water resistance. This is due to large water intake by natural fiber polymer composites may result in dimensional changes, and hence deteriorating its mechanical properties[7]. In this study, kenaf fiber was used as filler and added into LLDPE/PVA blends. The effect of increasing kenaf loading on the processing torque and water absorption of KNF-filled LLDPE/PVA composites was studied.

1. Experimental

1.1. Materials

Linear low density polyethylene (LLDPE) was supplied by PT. Lotte Chemical Titan Nusantara, Indonesia with a melt flow rate of 1 g/10 min at 190°C and a density of 0.92 g/cm^3. Polyvinyl alcohol (PVA), was supplied by Sigma-Aldrich (M) Sdn. Bhd., with a molecular weight of 89,000 to 98,000 g/mol and density of 1.269 g/cm^3. Kenaf (KNF) was obtained from National Kenaf and Tobacco Board (LKTN), Kelantan, Malaysia. KNF was subjected to grinding process to yield average KNF particle size of 75µm.

1.2. Composites preparation

KNF were dried in vacuum oven at 80°C, 24 hours prior being used in the composites preparation. The weight ratio of LLDPE/PVA was maintained at 60:40 (by weight percent, wt. %), with different KNF loading (i.e. 0, 10, 20, 30, 40 phr). The melt compounding of a series of LLDPE/PVA/KNF composites were performed in an internal mixer (Thermo Haake Polydrive, Model R600/610) at temperature and rotor speed of 150°C and 50 rpm, respectively, for 10 min. The compounded samples were then compression molded at 150°C into 1 mm thickness sheet using an electrically heated hydraulic press (GoTech Testing Machine, Model KT-7014 A).

1.3. Water absorption

The water uptake test was carried out in accordance to ASTM D570. The specimens were first dried in an oven for 24 hours at 50°C until a constant weight was obtained. Weight difference after immersion was recorded by weighing them periodically on a Sartorius balance Model: BS224S, with a precision of 1 mg. The excess water on specimen surfaces was removed with tissue paper before weighing. The water uptake test was performed for 30 days and the percentage of water uptake was calculated using Equation (1),

$$W_t(\%) = \frac{W_2 - W_1}{W_1} \times 100 \quad (1)$$

Where W_t is the total water uptake by the specimen, and W_1 and W_2 are the weights of the specimen before and after immersion in distilled water respectively.

2. Results and discussion

2.1. Processing torque

Fig.1 illustrates the processing torque against time of KNF-filled LLDPE/PVA composites. The curves of processing torque for all the composites are of similar trend against time. Initially, the torque increased rapidly when LLDPE were loaded into the mixing chamber. LLDPE then undergo melting which resulted in lower torque value. After 2 min, once again the torque increased rapidly due to loading of PVA. The increment is due to the resistance exhibited by PVA in LLDPE. Ismail *et al.* 2010 also reported the similar finding[8]. Then, the torque continues to decrease due to melting of PVA. At 6 min, KNF was loaded to the mixing chamber and torque value was found to increase. This is due to the resistance KNF in LLDPE/PVA matrix. The torque then gradually decreased and reached a stable value at the end of mixing time of 10 min.

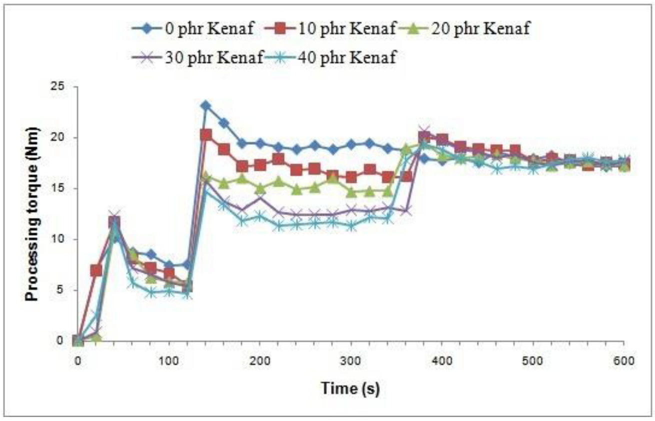

Fig. 1. Processing torque against time of KNF-filled LLDPE/PVA composites.

Table 1 illustrates the stabilization torque of KNF-filled LLDPE/PVA composites at the end of mixing time (10 min). Stabilization torque can be used as a direct measurement of the viscosity of a polymer melt mixture.[9,10] It can be seen in Table 1 that the value of stabilization torque increases with increasing KNF loading from 10 to 40 phr. The increment is due to more interactions happened between KNF fibers and LLDPE/PVA matrices. Hence, the viscosity of the composites increases and higher torque reading was recorded at higher KNF loading. Composites with 40 phr KNF gives the highest stabilization torque value can be explained by the existence of interactions between KNF fibers and LLDPE/PVA matrices and also KNF-KNF fibers itself.

Table 1. Stabilization torque of KNF-filled LLDPE/PVA composites.

KNF loading (phr)	0	10	20	30	40
Stabilization torque (kN)	17.1	17.3	17.4	17.6	17.8

2.2. Water absorption

Fig. 2 illustrates the water absorption of KNF-filled LLDPE/PVA composite as a function of immersion time. For LLDPE/PVA matrix, initially the water absorption was increased rapidly, and then remains almost constant until reaching its equilibrium point at about ~35 days. The water absorption of LLDPE/PVA matrix is due to the presence of hydrophilic hydroxyl group in PVA. For the water absorption test of all the KNF-filled LLDPE/PVA composites, it was found that the color of the distilled water change to light brown. This finding indicates that leaching of PVA from the composites has occurred and results in KNF detachment from the composites.[11] It was observed that for all KNF-filled LLDPE/PVA composites, water absorption increases immediately for the first day and then decreased after 2 days of immersion. However the water absorption again increased slightly until the 7th day before decreased gradually again in a very slow rate. The decrement is due to leaching of PVA that causes LLDPE/PVA matrix unable to hold KNF in the composites. Therefore, KNF was leached out and the color of distilled water turn into light brown color when time prolonged.

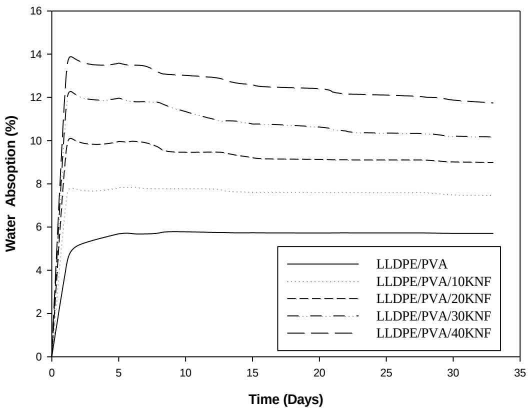

Fig. 2. Water absorption of KNF-filled LLDPE/PVA composites.

It was seen in Fig. 3 that the equilibrium water absorption of KNF-filled composites increases with increasing KNF loading from 10 to 40 phr. The structure of KNF itself consists of hydroxyl groups, which gives KNF the hydrophilic nature and tendency to form hydrogen bonding when reacted with water. Thus, with increasing KNF loading, hydroxyl groups of KNF increased and results in greater water absorption. Balakrishna *et al*. 2012 and Seong Chun *et al*. 2013 also found that greater amounts of hydroxyl groups are available to bond with water at higher filler loading levels[12,13]. The other reason for the increasing water absorption is due to the weak interfacial adhesion between the KNF and the LLDPE/PVA matrix. The weak interfacial adhesion may cause formation of microcracks or voids that allow water to be absorbed by the composite.[9] Tan *et al*. 2014 reported that the water absorption ability of kenaf fiber-PVA composites comes from the water absorption properties of both the kenaf and the PVA.[11]

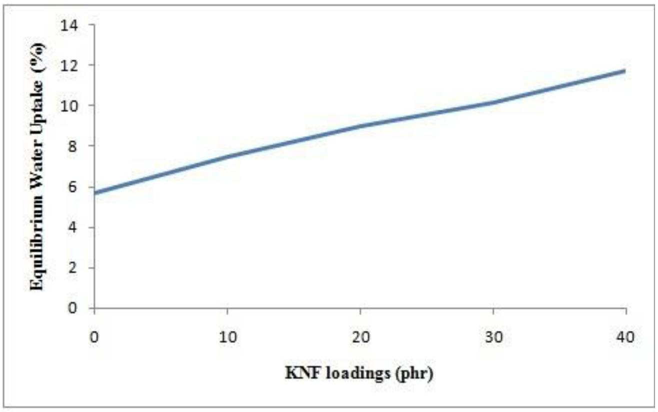

Fig. 3. Equilibrium water absorption of KNF-filled LLDPE/PVA composites.

3. Conclusions

The processing torque of KNF-filled LLDPE/PVA composites was increased with time. Stabilization torque was increased with KNF loading, and composites with 40 phr KNF give the highest stabilization torque value of 17.8 kN. The water absorption of all the KNF-filled LLDPE/PVA composites were increased at the first few days, and then decreased slowly. The equilibrium water absorption of KNF-filled LLDPE/PVA composites was increased with increasing KNF loading.

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