Studies on water absorption of polypropylene/ recycled acrylonitrile butadiene rubber/ empty fruit bunch composites

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Abstract. Water absorption study is important in natural fibres polymer composites since they are hydrophilic in nature. In this study, water absorption properties of thermoplastic elastomer composites with the incorporation of empty fruit bunch (EFB) fibres were examined. The polypropylene (PP) matrix, recycled gloves (NBRr) and EFB fibre were mixed together using a heated two-roll mill machine at 180°C. A compatibilizer of polypropylene maleic anhydride (PPMAH) was added to improve the water resistant properties of the composites. Water absorption test was conducted by long-term immersion in distilled water at room temperature. From the analysis, the percentage of water absorbs for PP/NBRr/EFB composites was increase as the NBRr loading increases. However, it is interesting to observe that the percent of water absorbs from PPMAH compatibilized composites was decreases from 20 % to 15 % with the highest NBRr loading. It shows that PPMAH compatibilizer possibly acts as a protective barrier and enhances the interfacial adhesion between the fibre and matrices.

Keywords. Water absorption, thermoplastic elastomer, polypropylene maleic anhydride, recycled glove, empty fruit bunch

1. Introduction

The growing of environmental awareness has drive most of researchers to use the natural plant fibres in a polymer composite replacing the synthetic fibres. Natural fibres have their own applicability such as biodegradable, naturally less abrasive, vast availability and low-cost production [1–3]. Bamboo, sisal, jute, hemp, flax, rice husk, kenaf and oil palm fibre are the examples of plant fibres used as filler in polymer composite [4–6]. Malaysia as a tropical country generates about million tons per year of renewable biomass from oil palm industry such as oil palm trunks (OPT), oil palm fronds (OPF) and empty fruit bunch (EFB) [7]. EFB is preferable due to the excessive of biomass generated from the palm oil industries [8]. Several attempts have been made to utilized EFB in the fabrication of natural fibre polymer composites [9]. The most commonly used thermoplastic matrices to work with are polyethylene (PE), polystyrene (PS) and polypropylene (PP). Whereas thermoplastic elastomers (TPE) is the rapidly growing polymer types, that was fabricated from the combination of thermoplastic and the rubber elastomer [3,10]. Additionally, the incorporation of natural fibre as filler in TPE is not only reducing the disposal problem but also produce low-cost of the end-products.

Recycling of waste materials is an idealistic method to overcome the environmental issues. The abundance of rubber wastes is mainly obtained from tires and gloves industries. Rubber gloves are usually found at the industries of automobile, chemical and also medical purposes. Usually, this glove was discarded after a single used and after that, dumped at the landfill. Most of the rubber gloves is hard to degrade which then subsequently will increase the soil and water pollution [11]. Thus, the use of rubber glove waste in polymer composites seems important to reduce the environmental problems and also to produce the new novel sustainable products. In this work, nitrile gloves waste or known as recycled acrylonitrile butadiene rubber (NBRr) was used with the combination of polypropylene (PP) as a matrix and empty fruit bunch (EFB) fibre as a filler. However, the composites are usually weak at the interfacial bonding. This was due to the different polarity of hydrophobic polymer and hydrophilic natural fibre. Besides, the natural fibres are consists of highly moisture content which can affect the long-term performance of the composites.

Therefore, the objective of this research is to study the water absorption behaviour of develop thermoplastic elastomer, PP/NBRr/EFB composites with the addition of polypropylene maleic anhydride (PPMAH). Based on the literature, no research was reported on the study of water absorption of PP/NBRr/EFB composites with and without PPMAH which act as compatibilizer to improve the composites performance.

2. Material and Method

2.1. Material Preparation

The isotactic polypropylene (PP), grade 6331, from Titan PP Polymers (M) Sdn. Bhd, was used as the thermoplastic matrix. The melt flow rate of PP is 14g/10 min at 230 °C, and the density is 0.9 g/cm³. The rejected nitrile glove or known as recycled acrylonitrile butadiene rubber (NBRr) from Juara One Resources Sdn. Bhd. was used. Firstly, NBRr gloves were cut and masticulated into small particle size via two-roll mill machine. Then, NBRr particles were sieved into particular size about 150 μm to 300 μm. While for the filler, empty fruit bunch (EFB) fibre was collected from United Oil Palm Industries Sdn. Bhd. EFB was first cleaned to remove the impurities and dirt prior put in the oven with temperature 90°C for 24 hours to eliminate excessive moisture. Then, it was grinded into powder form and sieved into particular size of 150 μm to 300 μm. Whereas, for the PPMAH compatibilizer, it was gained from the Sigma Aldrich Chemical with the percentage of grafting 8-10% and melt flow index of 11.5 g/10 min.

2.2. Mixing compounding and sample preparation

The composition used in this study for PP, NBRr, EFB, PPMAH and the steps in preparing the compounds are shown in Table 1 and Table 2, respectively. A heated two-roll mill machine from Fang Yuan Instrument (DG) Co. was used to mix all the materials with temperature 180°C and rotor speed of 15 rpm. After mixing, the compounds were dried for 24 hours at 80˚C under vacuum. The compounded samples were compression-moulded into 1 mm thin sheet at 180˚C, using a hot press machine, model GT 7014 A with 6895 kPa. Seventh minutes of preheating followed by two minutes of compression were carried out. Then, samples were continued for two minutes of cooling compression. Based on the ASTM D638, a dumbbell shape samples was prepared using a Wallace die cutter model S6/1/6.A.

Table 1. Composition for PP/NBRr/EFB and PP/NBRr/EFB/PPMAH composite.

Materials	PP/NBRr/EFB (phr[a])	PP/NBRr/EFB/PPMAH (phr[a])
PP	100, 80, 70, 60, 50, 40	100, 80, 70, 60, 50, 40
NBRr	0, 20, 30, 40, 50, 60	0, 20, 30, 40, 50, 60
EFB	10	10
PPMAH[b]	-	5

[a]part per hundred resin
[b]The weight of PPMAH dependent on PP

Table 2. Mixing sequences.

PP/NBRr/EFB		PP/NBRr/EFB/PPMAH	
Time (min)	Materials	Time (min)	Materials
0	PP	0	PP
4	NBRr		PPMAH
6	EFB	4	NBRr
9	Discharging	6	EFB
		9	Discharging

2.3. Water Absorption Test

For the water absorption test, 5 dumbell specimens of each formulation were weighed (W_0, initial weight) prior to immersed in distilled water at room temperature. The specimens were taken out from water at regular intervals and wiped with filter paper. The weight gains after exposure (W_m) were recorded using a weighing balance with a precision of ± 0.001 (1mg). The samples continue re-immersed until the saturation limit was reached. The moisture content at any time t, (M_t) as a result of moisture absorption, was calculated by using Eq. 1 [12],

$$M_t = \frac{W_m - W_o}{W_o} \times 100 \quad (1)$$

3. Result and discussion

Figure 1 shows the water absorption percentage as a function of the square root of time for PP/NBRr/EFB composites. At the initial stage, water is rapidly absorbs into the composites. Then, water slowly absorbs with the prolong immersion time until it attained to a saturation level. It was observed that the percentage of water absorption of PP/NBRr/EFB composites is varied from 5.3 to 20 %. When PP/NBRr/EFB composite is exposed to the wet condition, water are easily reacted and penetrated onto the hydrophilic structure of fibre. Hemicellulose is the main fibre component that are responsible for the water absorption in natural fibres [13]. The process of fibre swelling due to water penetrate will develop stress at the interface between fibre and matrix which then, leads to microcracking mechanisms. This will increase the capillary of water transport into the composites. From the result obtained, percentage of water absorption increases as more NBRr loading increase. This trend is due to the less embedded of NBRr particles to the PP matrix. Thus, the composites will presented more voids and gaps as more NBRr added. A sufficient amount of EFB fibre and NBRr matrix is required to avoid the poor wettability and non-homogeneous of composites. Besides, the voids formation are also due to the water vapour generates during the mixing process [14]. Figure 2 shows the illustration of water retains in PP/NBRr/EFB composite. Numerous studies have attempted to explain the water absorption effects on natural fibre reinforced polymer composites [9,15,16].

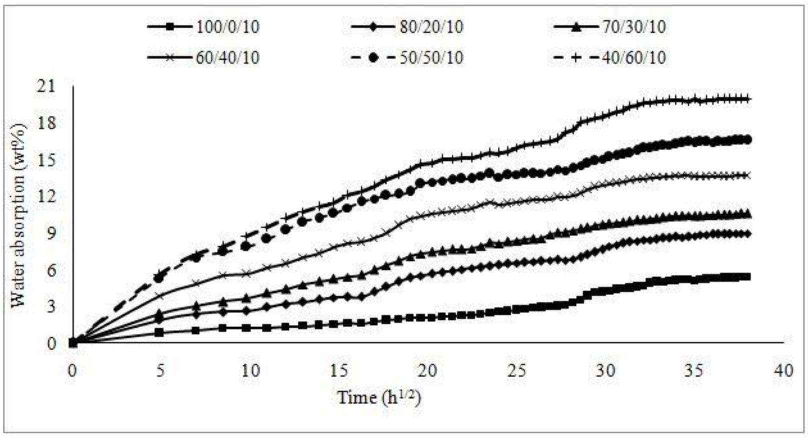

Figure 1. Percent increase in water absorption of PP/NBRr/EFB composites.

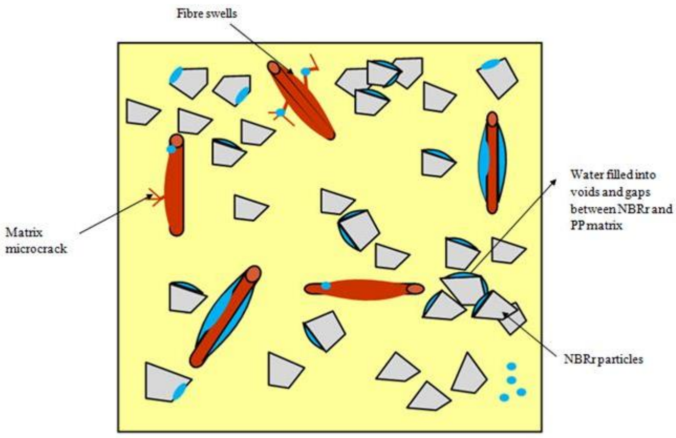

Figure 2. Illustration of water retains in the PP/NBRr/EFB composites.

However, further reduction of water absorption percentage of PP/NBRr/EFB/PPMAH composites is observed (as shown in Figure 3). The water absorption varies between 2.8 to 15 %. PPMAH compatibilizer has a tendency to reduce the water absorption rate. The anhydride group from PPMAH may react with the freely hydroxyl groups of the EFB fibres via C-O-C esterification reaction [17] by blocking some of the EFB hydrophilic ends. The PPMAH compatibilizer also functionalizes as a protective barrier by encapsulating the EFB fibres with the PP matrix. Besides, data obtained shows that, the saturation time of PPMAH compatibilized composites shows slightly increases. This prove the PPMAH compatibilizer gains the ability to resist water uptake and also lowering the velocity of moisture diffuse into the composites [18].

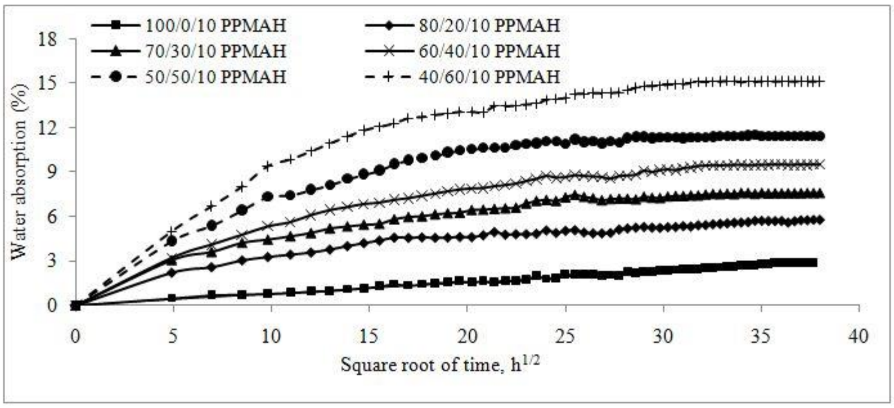

Figure 3. Percent increase in water absorption of PP/NBRr/EFB/PPMAH composites.

In short, there are two major mechanisms relates to water uptake of PP/NBRr/EFB composites. The first mechanism was due to the existence of natural fibre, which increases the hydrophilicity of the composite. When PP/NBRr/EFB composite is exposed to the moisture, water easily penetrates into the hydrophilic groups of natural fibre, which can reduce the interfacial adhesion between the fibre and matrix. Swelling of cellulose fibres leading to micro-cracking in the matrix which promotes capillarity transports [19]. The second mechanism was due to the additional of NBRr rubber particles which then disturbing the structural homogeneity of the compound. A sufficient amount of NBRr is needed to avoid the agglomeration. More voids formed if the NBRr matrix particles is too much, which will increase the ability of water uptake into the composites. Therefore, the addition of compatibilizer or other chemical reagent is required in order to improve fibre-matrix adhesion and reduce the water absorption by the composites.

4. Conclusion

Water absorption percentage of PP/NBRr/EFB composites is increasing as NBRr content increase. This was due to the voids formation during the compounding process. However, for the PPMAH compatibilized composites, the water absorption percentage is reduced. The presence of MAH moieties of PPMAH gave better adhesion between the fibre and matrices. PPMAH is one of the compatibilizer that can be used to resist water absorbs from the surrounding and improve the composites performance.

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