Effects of Coupling Agent on Mechanical Properties and Water Absorption of Oil Palm Frond-Polypropylene Composite

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Abstract

Oil palm frond is reported to be the biggest amount of solid biomass from oil palm plantation. In supporting the zero burning system implied today, the cut fronds are left at the plantation as natural fertilizers. The main idea in this research is to utilize the leftover cut fronds as filler in polypropylene matrix composite rather than for bio-fertilizers. However, the hydrophilic natural particles tend to have difficulties to be encapsulated by the hydrophobic matrix. Thus, this paper investigated the effectiveness of coupling agent to improve the interfacial adhesion between oil palm frond and polypropylene matrix. Composites with two different particle sizes were fabricated with 0% and 3 wt% coupling agent through hot-press moulding. The findings of maleic anhydride polypropylene (MAPP) variable performed a significant difference at 95% confident level in all tested samples except for the flexural modulus and impact strength. In general, MAPP improved the composite properties of flexural, tensile, impact and water absorption behaviour.

Keywords: Oil Palm Frond, Polypropylene, Maleic Anhydride Polypropylene

1. INTRODUCTION

1.1 Oil palm plantation

Oil palm tree (Elaeis guineesis) is an agricultural plant consists of non-woody fibres, lignocellulosic material, originally from West Africa and is widely cultivated in Malaysia for its oil producing fruits. In the year 1960s, Government's agricultural diversification programme has started to widely cultivate the oil palm tree plantation with the intention of reducing dependency on rubber and tin (Anon, 2012). Today, oil palm tree are available in abundance as the plantation area is the largest in Malaysia with 4.49 million hectares of plantation forestry.

The great expansion of oil palm tree plantation in this country has generated the massive amounts of residues such as oil palm frond (OPF), oil palm trunk and empty fruit bunches which may create the problems of during replanting operation. Great environmental problems may be created if the residues are left to be burn. Furthermore, there is problem of burning these residues as they high moisture. The residues may take up to five years to be degraded naturally and this will be a disturbance to the oil palm plantation activities and thus something that wasteful to the industry.

1.2 Lignocellulosic plastic composite

Lignocellulosic thermoplastic composite can be defined as a material made by a combination of petroleum derived polymers and bioresource (Shinoj, Visvanathan & Panigrahi, 2010). The constituents are chemically and physically dissimilar and are separated by a distinct interface. According to Sumaila et al., (2006), the composite consists of a continuous matrix which surrounds the filler and provides the reinforcement, resulting in good performance properties of both the matrix and filler.

1.3 Polypropylene

Of all the thermoplastic matrices available, polypropylene (PP) shows the most potential benefits when combined with natural fibres in making composites for industrial applications (Kim et al, (2007) , Igawa & Nakamura, (2001). They pointed out that, natural fibres as a substitute for glass fibres in composite components, have gained renewed interest in the automotive industry.

In manufacturing plastic industries, there are two types of PP that commonly used which is the stereospecific and random polymer. Stereospecific PP is made by polymerizing PP in the presence of a stereospecific catalyst. It is more rigid and has better resistance towards elevated temperature than random PPs.

1.4 Maleic anhydride polypropylene

The fabrication of oil palm frond-polypropylene (OPF-PP) composite may have bonding problem attributed to the different behaviour of both main substances. OPF has a hydrophilic characteristic which tends to absorb water while the matrix has a hydrophobic behaviour which has a very minimal stage of water absorption. They have different polarity which tends to disturb the adhering process to each other's surfaces. Thus, maleic anhydride polypropylene (MAPP) is introduced to the composite as a coupling agent. Coupling agent benefited the composite in two ways which are to interlock with the hydroxyl groups of the cellulose and the other end is to interact with the functional groups of the polymer matrix (Zampaloni, et al., 2007).

The addition of coupling agent such as MAPP will allow reaction between the hydroxyl group of wood filler with the maleic anhydride functionality and this may result in better compatibility to each other. Free hydroxyl group will then be fewer which resulted in slowing down the rate of the composite to absorb water (Bledzki et al., 2005). This is also supported by (Bledzki, Mamun and Volk, 2010) saying that, the adhesion between the filler and polymer matrices may be improved by using coupling agents. They found that the compatibilizer will enhance the tensile strength and impact strength of the composite. The effects resulted from the interfacial bonding between the compatibilizer and hydroxyl group on the wood surface.

This study intended to 1) explore the feasibility of OPF to be filler in the PP matrix and 2) investigate the composite mechanical properties and water absorption behaviour with relation to the effect of MAPP coupling agent addition.

2. METHODOLOGY

2.1 Materials

The OPF were obtained from a local oil palm tree plantation at Universiti Teknologi Mara, Pahang. The matrix polymer is PP homopolymer in the form of pellets supplied by local manufacturer. It has a melt flow index of 33g/10min at 230oC and melting temperature of 163oC. MAPP the compatibilizer has molecular weight and maleic anhydride grafting level of 40 000 g/mol and 5 % respectively.

2.2 Method

The OPFs were cut into smaller width using a narrow band saw. They were then chipped and flaked to yield particles. The particles were air dried within a week before the screening process and the finest size dust residue from the process were collected and ground. Sizes of 250 and 425 µm were used as filler and PP was used as the polymer matrix.

Compression moulding process was conducted by consolidating the OPF-PP pellets in a stainless steel mould with two different dimensions: a) 24cm x 15cm x 0.6cm for bending test and b) 30cm x 24cm x 0.2cm for tensile, impact and water absorption test.

The tests upon the flat pressed composite were performed in accordance to American Society for Testing and Materials (ASTM) standard. Preparation of specimens tested was done according to ASTM D 790-92 for flexural test (Klyosov, 2007), ASTM D 638M-91a for tensile test (Khalid et al., 2008), impact test (Morreale et al., 2008) and ASTM D 570-81 for water absorption (Premalal, Ismail and Baharin 2002).

3. RESULTS

3.1 Descriptive statistics

Table 1 enumerates the descriptive statistics of uncoupled and coupled composite at 10 wt% OPF content. Seven properties were evaluated to explore the effects of MAPP addition as coupling agent. The properties of flexural modulus, tensile strength, tensile modulus and elongation at break increases when coupling agent is added for both 250 and 425µm particle size. The other properties in the other hand only show increment with the effect of coupling agent at 250µm. The composite shows good water absorption behaviour with the addition of MAPP with negligible 0.01% difference between 250 and 425µm particle size. In general, a positive trend could be observed when MAPP is added to the sample.

Table 1: Descriptive statistics for 10% filled OPF-PP composite

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CA %	Size, µm	Flexural properties		Impact properties	Tensile properties			Physical property
		MOR [Mpa]	MOE[Mpa]	Impact[kJ]	MOR[Mpa]	MOE[Mpa]	Elong[%]	WA[%]
0	250	38.73 (0.53)	2246 (11)	3.27 (0.16)	16.67 (0.33)	2380 (41)	5.25 (0.15)	0.24 (0.012)
	425	45.16 (0.52)	2203 (10)	4.30 (0.16)	21.87 (0.32)	2369 (40)	6.06 (0.15)	0.40 (0.012)
3	250	43.85 (0.4)	2263 (9)	4.09 (0.14)	23.47 (0.29)	2696 (36)	7.26 (0.14)	0.25 (0.01)
	425	39.09 (0.49)	2343 (10)	3.72 (0.15)	22.07 (0.31)	2589 (38)	6.79 (0.14)	0.31 (0.011)

Note. CA, coupling agent -MAPP; MOR, modulus of rupture; MOE, modulus of elasticity; Elong, elongation; WA, water absorption , Standard deviation in bracket (SD)

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3.2 Flexural properties

Flexural properties include the readings of the modulus of rupture (MOR) called as strength and modulus of elasticity (MOE) called as modulus. Flexural strength is the ability of the material to withstand the bending forces applied perpendicular to its longitudinal axis (Natchtigall et al., 2007). Figure 1 exhibits the Flexural MOR that is 13.29% improved with the addition of MAPP as compared to the control sample and this percentage has a significant difference at 95% confident level. The MOR of uncoupled sample interprets the larger amount of failed points to withstand the forces upon the sample. The interaction between the OPF particles and PP matrix is improved with the help of MAPP and thus prepared the sample to be stronger to resist the forces applied upon the sample. Addition of MAPP as coupling agent to fabricate the composite however gives no significant effect in increasing the flexural modulus.

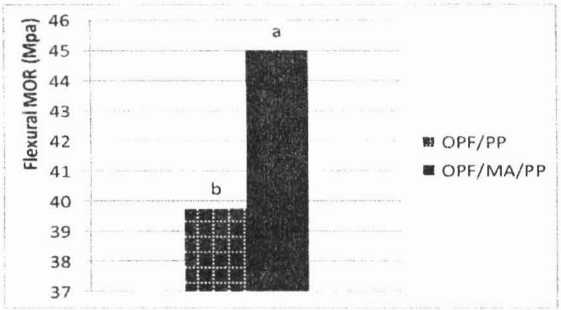

Figure 1: Effect of MAPP on flexural strength

3.3 Tensile properties

Tensile properties may explain the stress transference between the filler and matrix. A good interfacial adhesion between the two substances may contribute in good stress transfer and subsequently improved tensile properties. The composite shows an enhancement in tensile strength when coupled with 3% MAPP as observed in Figure 2. The effect has significant different between uncoupled and coupled sample with 19.71MPa and 23.14MPa respectively. From this finding, it can be seen that the coupling agent plays a prominent role towards improvement of tensile strength.

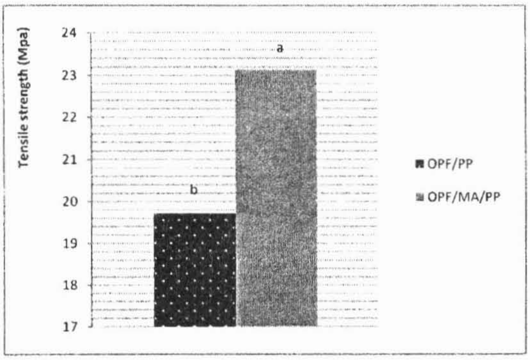

Figure 2: Effect of MAPP on tensile strength

Tensile modulus that also plays a role of stiffness may be affected by the cellulosic molecular orientation (Khalid et al., 2008). Figure 3 also exhibits the same trend of increment as coupling agent is added to the composite. This may be attributed to a good particle dispersion that tends to contribute in a well orientation of the particles in the coupled sample.

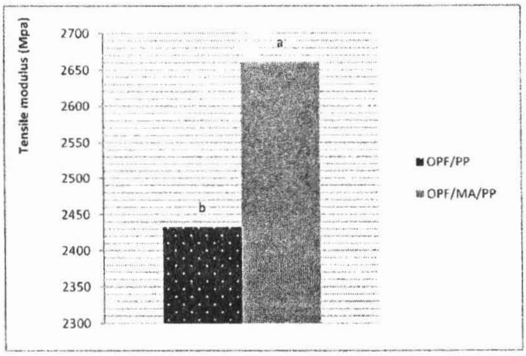

Figure 3: Effect of MAPP on tensile modulus

Incorporation of filler in a thermoplastic composite may abruptly drop the elongation at break as compared to the neat plastic matrix (Khalid et al., (2008), Morreale et al., (2008). However, the addition of coupling agent may contribute to higher OPF-PP elongation at break. It can be seen from Figure 4 that 3 wt% MAPP has improved the elongation at break of the sample. This means that more energy is required to fracture a specimen containing MAPP coupling agent, compared to the uncoupled sample.

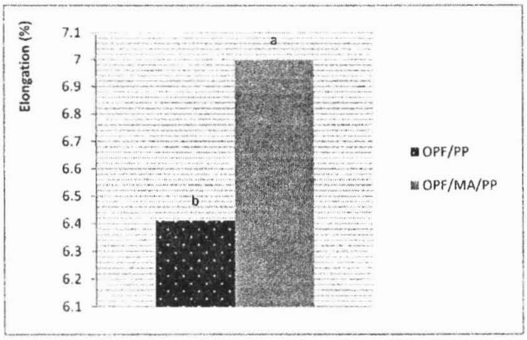

Figure 4: Effect of MAPP on elongation at break

3.4 Impact properties

The 3 wt% MAPP added in the sample improves the impact strength of the composite. However, the 7% strength increment from 3.59 to 3.85 MPa is not significantly different compared to the uncoupled control sample.

3.5 Water absorption

3wt % MAPP is observed in Figure 5 to be sufficient to act as coupling agent to improve the water absorption behaviour of the OPF-PP composite. This statement is supported with the results of water absorption that exhibits the decrement percentage. This may be attributed to the limitation of water to penetrate into the OPF that is encapsulated by the matrix. Hydroxyl groups on the filler surface may has established a bond with the functional groups of the coupling agent that latter reduce the bonding of cellulosic filler with water (Premalal, Ismail and Baharin, 2002).

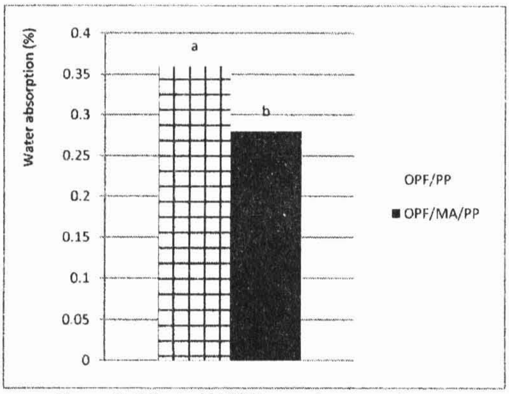

Figure 5: Effect of MAPP on water absorption

4. CONCLUSIONS

OPF particle is feasible to be filler in thermoplastic composite. Considering the weakness of 425µm particle size in water absorption, this may be reduced by the addition of MAPP. Both particle sizes of 250 and 425µm gave similar properties values. Addition of 3 wt% MAPP has improved all of OPF-PP composite properties.

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