Tensile and morphological studies of polypropylene/empty fruit bunch composite: Effect of maleic anhydride-grafted polypropylene

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Abstract. The effect of maleic anhydride-grafted polypropylene (PPMAH) as compatibilizer on the tensile and morphological properties of polypropylene (PP)/empty fruit bunch (EFB) composite were investigated. The composite was melt mixed using a heated two roll mill at 180 °C with speed of 15 rpm for seven different EFB filler loadings (70/30, 75/25, 80/20, 85/15, 90/20, 95/5 and 100/0 wt%). From the analysis, tensile strength and elongation at break decreased with increasing EFB filler loading. However, it is interesting to observe that the addition of PPMAH has resulted in 5 to 10% better tensile strength compared to without PPMAH compatibilizer. The morphological studies from scanning electron microscopy (SEM) of tensile fracture surfaces showed that PPMAH compatibilizer composites also indicates improved dispersion and adhesion of EFB fibre on the PP matrix.

Keywords. Maleic anhydride-grafted polypropylene, empty fruit bunch, polypropylene, tensile properties, compatibilizer

1. Introduction

Recently, with the increasing environmental consciousness and new government rules, the motive for manufacturing product has to be more suitable to the environment[1]. For over a decade, the application of biocomposites that consists of natural fibre and polymer has grabbed their attention due to its characteristic. Natural fibre like kenaf, jute, hemp and empty fruit bunch has been replacing from the conventional fibre such as glass and carbon[2–4]. Natural fibre has been a great solution for efficient and a very cheap absorbing material. They are also an ideal option due to their renewable nature and eco-friendly properties. Production of the composite using this fibre gives a low cost, low density, biodegradable, good thermal and insulating properties[5–7]. The usage of natural fibres as reinforcing fibres in thermoplastic and thermoset matrix composite produce a good environmental benefit along with ultimate disposability and uses raw material. These fibre have high toughness, acceptable specific strength and good thermal properties compared to glass fibres and mica[1].
Usually, natural fibre such as empty fruit bunch (EFB) is either burned or dumped in the plantation area for natural decomposition[8]. The uses of these fibres in a composite can reduce the amount of polymer used which eventually protect the environment and less polymer waste to be disposed[9]. Besides, usage of natural fibre is suitable as reinforcement in polymer matrix as it is available in abundance, requires easy processing and cheap[10]. However, natural fibres are naturally hydrophilic and thermoplastic have hydrophobic properties. The incompatibility of this two material will create poor interfacial adhesion and affect the performance of the composites[7, 8]. Compatibilizer is eventually used to enhance the interfacial adhesion between the fibre and matrix. Maleic anhydride-grafted polypropylene (PPMAH) is one of the compatibilizers, produced by letting the PP chain to link with maleic anhydride and form covalent bonds at the interface between fibres with PPMAH[13].

Thus, this study is aimed to investigate the tensile properties, which consist of tensile strength, Young’s modulus, elongation at break, and morphological properties of the PP/EFB composite with and without the PPMAH compatibilizer. The effect of EFB filler loading on the composite is also taken into consideration.

2. Material and method

2.1 Material Preparation

PP grade 6331 as a matrix was supplied from Titan Pro Polymers (M) Sdn. Bhd. EFB fibre from United Oil Palm SdnBhd was cleaned to remove all the impurities such as dried leaves and dirt. EFB was then cut and resized into small pieces. Next, the cleaned EFB was dried in the oven with a temperature of 90°C for 24 hours to remove the moisture content. It was ground into powder form and sieved into the particular size less than 150 µm. The EFB powder dried again in the oven to remove excessive moisture content at the same temperature as earlier for 24 hours. PPMAH was supplied from Sigma Aldrich chemical.

2.2 Mixing compounding and sample preparation

The materials were prepared and weighed according to the formulation as shown in Table 1. PP and EFB were mixed using a heated two roll-mill machine at 180°C with a rotor speed of 15 rpm. The PP was first charged into the machine and followed by EFB powder at first four minutes. The total mixing time is 7 minutes. For the compounding with PPMAH compatibilizer, it was added simultaneously with PP. Then, all the compounds were compressed using a hot press machine at 180°C. The compounds were preheated for three minutes prior to being compressed for four minutes. The 1 mm thin sheet was allowed for cooling for another three minutes. It was cut into dumbbell shape using Wallace die cutter model S6/1/6/A. Each sample was prepared with five duplications.

| Materials | PP/EFB (wt%) | PP/EFB/PPMAH (wt%) |
|-----------|--------------|---------------------|
| PP        | 100 95 90 85 80 75 70 | 100 95 90 85 80 75 70 |
| EFB       | 0 5 10 15 20 25 30 | 0 5 10 15 20 25 30 |
| PPMAH*    | - - - - - - | 3 3 3 3 3 3 |

*the weight percent of PPMAH is dependent on PP

2.3 Testing and characterization properties

2.3.1 Tensile properties

Tensile tests were performed on the samples using an Instron Universal Testing Machine. Tensile tests were conducted according to ASTM 638 Standard Test Method to determine tensile strength, Young’s Modulus and elongation at break. The thickness and width of each dumbbell specimens were recorded using a vernier caliper and the initial jaw separation distance on the tensile tester was set to 50mm. All
dumbbell specimens were tested with a crosshead speed of 5mm/min. The sample was clamped at both ends with one end fixed to the machine and the other end at the removable clamp. Loads were applied until the samples were broken. All five tests were conducted for each type of sample and the average values are reported.

2.3.2. Morphological properties

Scanning electron microscope (SEM) was used to identify the surface morphologies of the fracture tensile specimens. Prior to the SEM testing, an auto fine coater was used to coat all the specimens with platinum to avoid charging effect. The tensile fracture and cross-sectional micrographs were taken to study the fracture mechanisms and interface adhesion of the composites. The SEM creates various images by focusing a high beam of electrons onto the surface of a sample and detecting signals from the interaction on the incident electrons with the surface of the sample.

3. Result and discussion

3.1. Tensile properties

The tensile strength of PP/EFB composites and PP/EFB/PPMAH composites is shown in figure 1. It can be observed that tensile strength decreases with increasing of EFB filler loading. This could be due to the incompatibility of the non-polar PP matrix with polar EFB which results in poor adhesion at the interfaces [14]. As the amount of fiber loading increase, low PP incorporation could result in insufficiency of the matrix to hold the EFB fiber. Thus, this occurrences affected the ability of the matrix to absorb and transfer the stress to the fibers[15]. However, PP/EFB/PPMAH composites have an improved tensile strength for almost 5 to 10 % compared composite without PPMAH compatibilizer. It is proved that the compatibilizer can improve the matrix-filler distribution in the composite. Addition of PPMAH has enhanced the rate of stress transmitted from the matrix to the EFB, which eventually result in a better connection at the interfacial region[16]. Addition of PPMAH has increased the adhesion by forming the C=C group’s reaction with the PP matrix[14].

![Figure 1. The tensile strength of PP/EFB composites with and without PPMAH compatibilizer.](image)

The Young’s modulus of PP/EFB composite with and without the addition of PPMAH is shown in figure 2. Young’s modulus was found to be increased with increasing of EFB filler loading[17]. This could be due to the addition of EFB filler into the PP matrix has improved the stiffness of the composite. Lignocellulosic filler in common has its natural stiffness, which is expected higher than the matrix [18]. Composite with the presence of PPMAHcompatibilizerhas a higher modulus than those with the absence of PPMAH. The modulus increases as the amount of filler increased and this indicates that the increased adhesion at the interfacial area might add the stiffness of the composite [19]. Addition of compatibilizer has strengthened the interfacial adhesion between the EFB filler and PP matrix, hence makes the bonding stiffer [20].
Figure 2. Young’s modulus of PP/EFB composites with and without PPMAH compatibilizer.

Figure 3 shows the elongation at break of PP/EFB composites with and without the addition of PPMAH. The elongation at break indicates a decreasing pattern with increasing fibre loading. The break of the sample at a lower value of deformation might due to the effect of rigid fibre disturbing the movement of the polymer network [21]. A decreased of elongation at break with a higher EFB filler loading may be due to the increased stiffness of the composite [18]. However, at similar EFB filler loading, PP/EFB/PPMAH composites have a lower elongation at break. Addition of PPMAH increased the interfacial adhesion resulting more rigid composite. Thus, it will reduce the elasticity or flexibility of the polymer chain [13].

Figure 3. Elongation at break of PP/EFB composites with and without PPMAH compatibilizer.

3.2. Morphological Properties
Figure 4 and figure 5 show micrographs of PP/EFB composite without and with PPMAH compatibilizer at EFB filler loading of 15 wt%, respectively. Figure 4 has revealed some of the EFB fibrepull-outsand created holes in the PP/EFBcomposite. The fibrepull-outs were due to the poor fibre-matrix interaction. This interaction will impair the properties of the composite such as poor tensile strength [22]. However, for PP/EFB/PPMAH composite as shown in figure 5, a better dispersion and adhesion is detected in the form of a more cohesive interface between the matrix and EFB fibre. The EFB fibre was nicely embedded in the PP matrix. Thus, these results serve as clear evidence that the compatibility between the EFB and PP is significantly enhanced upon reaction with PPMAH [23].
4. Conclusion

In short, the tensile strength and elongation at break decreased but Young’s Modulus increased with increasing of EFB filler loading. PP/EFB/PPMAH composite showed better tensile properties compare to PP/EFB composite. These findings were well supported by micrographs from morphological studies. The good adhesion and interfacial bonding between EFB fibre and PP matrix clearly observed with the addition of PPMAH compatibilizer.

5. References

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