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Effect of Maleic Anhydride on Mechanical Properties of Polylactic Acid (PLA) Composites Reinforced With Durian Skin Fibre (DSF)

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Abstract

Interfacial strength between polymer matrix and natural filler reinforcement had influenced the properties of durian skin fibre (DSF)/ polylactic acid (PLA) composite. Among the various ways to improve such properties, addition of maleic anhydride was found to be the most attractive and useful one. In this study, the effect of maleic anhydride on the mechanical properties of DSF/PLA composite was investigated. As for that, the composite profiles of PLA and DSF at 30% wt at different volume loading of maleic anhydride (2, 4 and 6% wt) were fabricated via melt blending process. Then, the mechanical properties such as tensile and flexural strength were evaluated. From the results, it can be seen that unfilled PLA/DSF composites significantly improve the tensile and flexural strength as well as modulus. The increment of maleic anhydride content in PLA/DSF composites decreased their tensile and flexural ability.

Keyword: Durian Skin Fibre (DSF), Polylactic Acid (PLA), Maleic Anhydride, Mechanical Properties

1. Introduction

Research toward polymer composite filled with natural organic filler in conjunction with recyclable polymer matrices had arisen for decades. This is because natural organic filler normally derived from wastes posses' low cost, non abrasive and degradable [1-2]. Other than that, it is capable to minimize the environmental problems and inculcate green technology awareness. It has been explored that role of natural fibres such as kenaf, flax and coir fibre as reinforcing materials improved the mechanical properties of polymer composites [3]. However, there were not much reported the role of durian skin fibre as reinforcement materials in polymer matrices. Thus, in this research, the potential of durian skin fibre as filler in polymer composite is introduced.

Durian skin fibre (DSF) were extracted from durian fruit that widely available around south eastern Asia country such as Thailand, Indonesia and Malaysia. As other natural fibre, durian skin fibre consists of cellulose, hemicelluloses, lignin and extraneous components. All these components make it suitable as the filler in polymer matrix as it responsible for better strength in the composite itself.

Generally, there are various types of matrices that can be reinforced by natural fibre such as metal matrix, ceramic matrix and polymer matrix [4]. Among those matrices, polymer matrix offers the most attractive one because it offers several advantages such as low density, easy processibility and low energy requirement [5]. There are two types of thermoplastic and thermoset polymers. Thermoplastic polymers are the most preferred matrix because it easy to fabricate and recyclable in comparison to thermoset polymers. There are many types of thermoplastic polymers. However, in this research, polylactic acid (PLA) was chosen as the matrix for durian skin fibre as PLA promotes better mechanical properties as well biodegradable compared to other polymers.

Polymer composite filled with natural fibres may not incompatible to each other and results in several disadvantages especially in term of its mechanical properties. To enhance the adhesion between matrix and filler, coupling agent such as maleic anhydride, silane, and copper amines can be used [6]. The aim of this paper is to study the effect of maleic anhydride as coupling agent on mechanical properties of polylactic acid (PLA) based with durian skin fibre (DSF).

2. Experimental Procedure

Polylactic acid (PLA) (grade 3051D) produced by NatureWorks®, China was used. Its specific gravity and melting temperature as well as glass transition temperature were reported at 0.998 g/cm3, 152.3 °C and 57-61 °C, respectively. Durian skin fibre (DSF) was obtained from the separation process of durian and its skin after being washed, grinded dried as well as sieved into 149 to 249 µm. The dried DSF was then treated with 4% vt of NaOH. On the other hand, maleic anhydride (Sigma Aldrich) which in powder forms was used as coupling agent. PLA and DSF was fabricated with 30 wt% ratios at various composition of maleic anhydride (2, 4 and 6 wt %). The mixing was carried out manually then extrudes using Thermo Hakke twin screw extruder where the temperature was 180 oC and screw speed was 100 rpm. After compounding, the composites were pelletized and went for injection molding by using BATTENFELD HM 600/850 injection moulding machine. Testing of samples for tensile and flexural strengths as well as modulus was done on computerized universal testing machine (LLOYSD) according to ASTM D-638. In order to observe the morphology of PLA/ DSF composite before and after mechanical analysis, scanning electron microscope (SEM, Fei Quanta 200) was used.

3. Results and Discussion

The effect of maleic anhydride on the tensile strength and modulus of PLA/ DSF composite are shown in Figure 1 and Figure 2. As illustrated in Figure 1, the tensile strength of PLA/ DSF composite decreases with the increases of maleic anhydride. On the other hand, the tensile modulus for the unfilled PLA/DSF composites is higher than the filled one. The tensile modulus is slightly similar to the PLA/DSF composites filled with 6 % maleic anhydride (Figure 2). It is undeniable that maleic anhydride enhanced the interfacial adhesion between matrix and fibre as well results in high tensile strength [7]. However, in this case, since DSF was first treated with NaOH and then with maleic anhydride, the pattern for tensile strength and modulus become decreased from the unfilled maleic anhydride to PLA/DSF composites until maximum filled one. The unfilled PLA/ DSF composite show the highest tensile strength and modulus compared to the filled one which is about 51.43 MPa and 1995.80 MPa. The addition of maleic anhydride after treated with NaOH weakens the structure of the interfacial adhesion between matrix and DSF. The results also suggest that NaOH alone already sufficient to strengthen the adhesions at the interface [8-9]. This is due to the fact that NaOH decreases the diameter and weight of the fibres due to the removal of lignin [9]. The addition of maleic anhydride after being treated with NaOH damages the structure of the fibre, thus decreased the tensile strength and modulus of the composite [10].

Figure 1. Effect of maleic anhydride content on the tensile strength of PLA/DSF composites

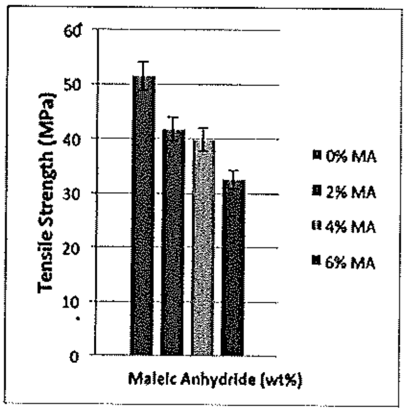


Figure 2. Effect of maleic anhydride content on the tensile modulus of PLA/DSF composites

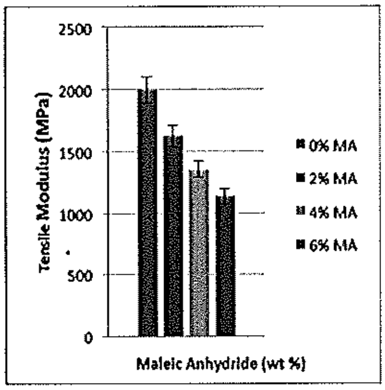


Figure 3 and 4 show the effect of maleic anhydride on the flexural strength and modulus of PLA/ DSF composites. From both figures, it can be seen that a variation of flexural strength and modulus appears upon the unfilled PLA/DSF composites in comparison to the filled maleic anhydride one. The results show that NaOH can give enough flexibility to the composite. This is because of the removal of lignin by NaOH interfibrillar region to be less dense and less rigid makes the fibrils more capable of rearranging themselves along the direction of stress loading [11]. The addition of maleic anhydride after that decreased its flexibility due to the excess delignification of DSF occurs resulting in a weaker or damaged fibre [12].

Figure 3. Effect of maleic anhydride content on the flexural strength of PLA/DSF composites

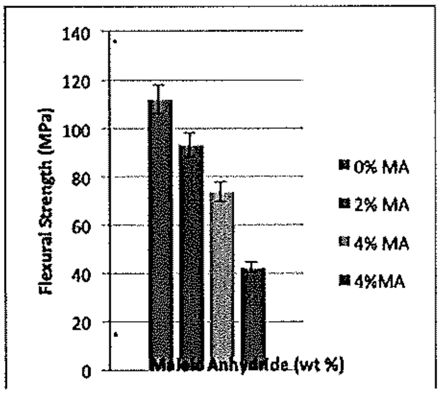
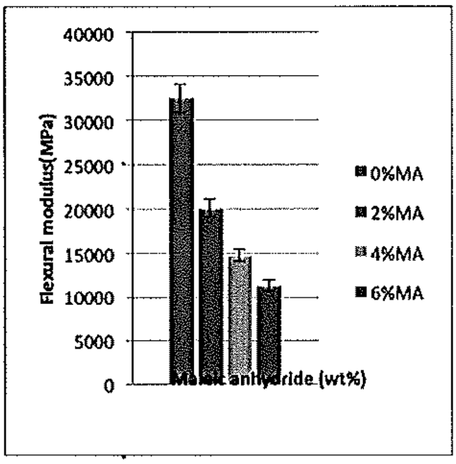


Figure 4. Effect of maleic anhydride content on the flexural modulus of PLA/DSF composites



The surface modification of the composites was observed and evaluated using scanning electron microscopy (SEM) in order to know the effect of maleic anhydride on the treated NaOH PLA/DSF composite. Surface morphology of unfilled PLA/DSF composite revealed the highest tensile and flexural strength as well as modulus in comparison to the surface morphology of 2 wt% maleic anhydride. Figure 5(a) and 5 (b) show the surface micrographs of unfilled PLA/DSF composite which is 30 wt% fibre loading and treated with NaOH only whereas Figure 6(a) and 6(b) illustrate the surface micrographs when 2 wt% of maleic anhydride was added to PLA/DSF composite.

Figure 5(a).SEM micrograph for unfilled PLA/DSF composite at 100x magnification

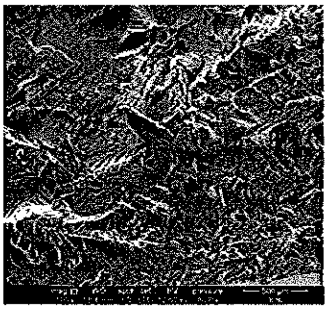


Figure 5(b).SEM micrograph for unfilled PLA/DSF composite at 500x magnification

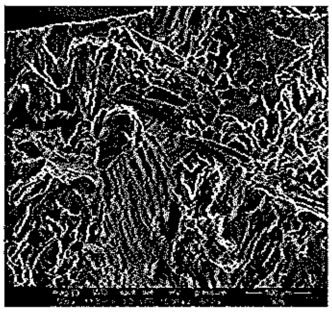
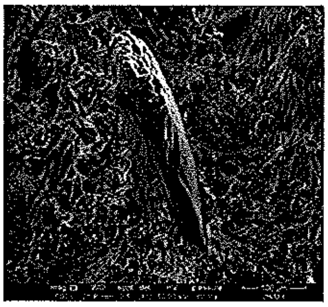


Figure 6(a).SEM micrograph for PLA/DSF composite with addition of maleic anhydride at 100x magnification

Figure 6(b). SEM micrograph for PLA/DSF composite with addition of maleic anhydride at 500x magnification



From Figure 5(a) and Figure 5 (b), it can be observed that there are less flaw present in PLA/ DSF composite in comparison to Figure 6 (a) and Figure 6 (b) that shows the influence of maleic anhydride. Figure 5(a) and (b) show better bonding between PLA and DSF without maleic anhydride which is clearly manifested as fewer voids. The influence of strength and modulus on composite was started from the existence of voids which leads to the brittleness and failure of the materials [13]. Figure 6 (a) and 6(b) show that maleic anhydride is not a good compactibilizer after the composite was treated with NaOH. The good adhesion can be induced without adding maleic anhydride. This good adhesion means the load can be transferred from matrix to filler.

4. Conclusion

The addition of maleic anhydride into PLA/DSF composite does not effect in the increment of tensile and flexural strength as well as modulus. From the data, the unfilled PLA/DSF posses better tensile and flexural strength and also modulus in comparison to other. However, further investigation need to be done in order to enhance the materials performance toward industrial application.

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