Tensile Properties and Impact Strength of RHDPE/BF Composites: The Effects of Chemical Treatment

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Abstract. Recycled high-density polyethylene reinforced with bamboo filler were compounded with twin-screw extruder and injection molding process. The main objective of this study is to investigate the effect of different chemical treatment with different concentration for bamboo filler reinforced with recycled high-density polyethylene composites via injection molding. The fillers were reinforced with plastic for different concentration of sodium hydroxide and acetic acid at 2.5 %, 5.0 % and 7.5 %. Mechanical measurements will show the presence of different chemical treatment with different concentration insignificantly effect in the composites tensile properties and also impact properties. The result of the mechanical analysis carried out showed that the presence of natural filler in composites will improve the properties of the material.

1. Introduction

Modern technologies required materials with unusual combination properties that cannot be met by conventional materials [1]. The composite material is invented by combining two different materials in new materials which may lead for a be better suited particular application either of the original materials alone and also to new desirable properties [1].

Actually, development of polymer composites starts in the 19th century that introduced new age research with the new option by using natural fibers as a part of more differentiated fields [2].
The increase in community interest and environmental consciousness, the unsustainable consumption of petroleum and new environmental regulations, led to thinking of the use of environmentally friendly materials. Natural fiber is considered one of the environmentally friendly materials which have good properties compared to synthetic fiber (Islam et al., 2015). Then, the use of natural fibers leads to cost reduction and lightweight composites, through the mechanical properties of natural fiber composites are much lower compared than the synthetic fiber composites [4].

Natural filler has a lot of advantages compared with synthetic filler. However, there is one major challenge in using natural filler include the bamboo filler which is the inherent flaws within fibres which is weak interfacial bonding to the thermoplastic bonding and high moisture absorption that reduce their compatibility with polymer matrices resulting in poor mechanical properties of the composites [5][6][7][8].

To avoid this problem, surface modification is required prior to composite fabrication. The properties of filler reinforced polymer composites may improve by using chemical treatment (sodium hydroxide, peroxides, isocyanides and maleic anhydride organosilanes) and physical (corona treatment, cold plasma treatment) [1][9].

Chemical modification on natural fiber will give a great approach for the establishment of covalent bonding between the filler matrix [10]. Here, it is used to alter the structure of the fiber, at the same time the interfacial adhesion between the polymer matrix and filler will improve the physical and mechanical properties of the composite material. Based on the previous research, surface modification by using a chemical treatment on filler can stop the moisture absorption, increase the surface roughness and clean the bamboo fiber surface [11][12][13].

2. Experimental Procedures

2.1. Materials
The recycled high-density polyethylene (RHDPE) will be supplied by Zarm Scientific and Supplies Sdn. Bhd. in solid pellet form with the melt flow rate of 0.236 g / 10 min at 200 °C, 5 kg load. RHDPE is the main matrix used for this study. Then, bamboo that was used as filler will be obtained around Perlis, Malaysia area. The bamboo flour will be sieved based on the required size using a vibratory sieve shaker AS 200 controls before undergoing the particle size analyzer (Malvern Sciro 2000 Mastersizer) for the particle size confirmation. Others chemical like sodium hydroxide (NaOH) and acetic acid (CH\textsubscript{3}COOH) will be supplied by ADV System Technology.

2.2. Chemical Treatment
Bamboo filler (BF) of 150-300 µm range size was used in this investigation. Two different chemical treatments by using NaOH and CH\textsubscript{3}COOH solution with concentrations ranging from 2.5 %, 5.0 % and 7.5 % [14][15] was prepared for alkaline and acid treatment. The BF was immersed in chemical solutions for 2 hours at the room temperature. After immersion, BF was washed several times with running distilled water to remove any excess of surface modification solution on the filler's surface. The pH of the filler was checked until it turns neutral. Finally, BF was dried in an oven at 45 °C for 12 hours period before proceeding to the fabrication stage of composites [16].

2.3. Composites Preparation
Different treatment of BF will be used in this study according to the formulation in Table 1. The composites were prepared by compounding using the twin screw extruder with a barrel temperature of 170 °C. The RHDPE mixed with BF will be loaded into the feeder and run through the twin screw extruder and produce composites pallet. Then, composites pallet will undergo an injection molding process for the final product and ready for further testing.
Table 1 The filler loading of the composites

| Parameters | Materials          | Formulation          |
|------------|--------------------|----------------------|
| Treated with NaOH | RHDPE / BF untreated | RHDPE / BF untreated |
| RHDPE / BF treated 2.5 % | RHDPE / BF treated 2.5 % |
| RHDPE / BF treated 5.0% | RHDPE / BF treated 5.0% |
| RHDPE / BF treated 7.5% | RHDPE / BF treated 7.5% |
| Treated with CH₃COOH | RHDPE / BF untreated | RHDPE / BF untreated |
| RHDPE / BF treated 2.5 % | RHDPE / BF treated 2.5 % |
| RHDPE / BF treated 5.0% | RHDPE / BF treated 5.0% |
| RHDPE / BF treated 7.5% | RHDPE / BF treated 7.5% |

2.4. Tensile Test

The tensile test specimens were prepared according to ASTM D638 with the common specimen for ASTM D638 that has a constant rectangular cross-section. The specimen size is 170 mm × 1 mm × 0.5 mm. The tensile testing was conducted using Axial-Torsion Universal Testing Machine (INSTRON-5982) at room temperature and all tensile specimens will be pulled under a constant crosshead speed of 50 mm/min. Each test was performed until tensile failure occurred. Before the test, the thickness of specimens will be measured using Vernier caliper. Five specimens will be conducted and average values were tabulated. The tensile test is the most common mechanical test to determine the tensile properties of natural fillers like tensile strength, Young's modulus and % of elongation.

2.5. Impact Test

Charpy impact test was conducted according to ASTM 790 at room temperature by using Compact Charpy Impact Tester (Model MAT 23). The specimen size is 80 mm × 1 mm × 0.5 mm. From this test, the fracture energy (Joule) will be determined. Five specimens will be conducted and the impact energy values will be averaged to obtain a mean value.

3. Results and Discussion

3.1. Tensile Properties

The effect of surface treatment on the mechanical properties by tensile analysis on tested material can be referred in Figure 1, Figure 2 and Figure 3 for tensile strength, elongation at break and Young's modulus result. Two different chemicals were used for chemical treatment which is sodium hydroxide (NaOH) and acetic acid (CH₃COOH) with three different concentrations.

Figure 1 illustrates the tensile strength RHDPE / BF composites of different chemical treatment with different concentration. The trend for NaOH show, increasing concentration of NaOH will decrease the tensile strength, while for CH₃COOH vice versa, which is increasing the CH₃COOH concentration will increase the tensile strength. Based on the result, it shows 2.5 % of NaOH displayed the highest tensile strength (25.195 MPa) compared to CH₃COOH at 7.5 % with (23.781 MPa). The treatment for alkaline improves the BF with small concentration used compared acid treatment.
The treatment gives better tensile strength compared to untreated BF due to the bonding of filler with matrix thereby improving the fiber-matrix interaction [17][18][19]. The significant of alkaline treatment is the disruption of hydrogen bonding in the filler surface, thus increasing surface roughness [19][20]. So, it improved filler-matrix interaction by the removal of hemicellulose and lignin that lead to the better incorporation of filler with matrix [21][22][23]. Unfortunately, tensile strength drop at 5% treated with NaOH due to the excess removal of cellulose content at the surface of the filler by the high concentration of alkali. So, it would damage the filler's structure [7][21]. Apart from that different type of natural filler and chemical have different optimum concentration during the treatment process which later affects the performance of the composites [21][24].

Figure 2 shows the elongation at break for different chemical treatment with different chemical concentrations. The optimum value of elongation at break for RHDPE / BF composites for both chemical treatments was a value of 28.16 %, CHCOOH and 61.92 %, NaOH with 5% of chemical concentration. The elongation at break of composites depends on the filler and matrix interaction which is composite with higher elongation, indicates higher ductility of materials and lower elongation indicates lower ductility of materials [25][26].
Based on Figure 3 below, it is clear that chemical treatment improves Young’s modulus of the RHDPE / BF composites. The trend was increasing from 2.5 % until 7.5 % concentration of both chemicals. The 7.5 % concentration NaOH and CH₃COOH of treated composites exhibit the highest modulus elasticity of 627.58 MPa and 806.08 MPa [7][27][28].

![Figure 3: Effect of treatment on Young’s modulus.](image)

3.2. Impact Properties
The detailed analysis of the Charpy impact test for all composites specimens is presented in Figure 4. The impact strength of alkaline treatment by NaOH give better impact strength compared with acid treatment by CH₃COOH. The highest impact strength is for NaOH treatment at 2.5 % with 2.662 J/m. Then, impact strength decrease with increasing of concentration for both treatments by NaOH and CH₃COOH. At 7.5 % concentration of NaOH and CH₃COOH, the value of impact strength was the lowest which is NaOH, 1.659 and CH₃COOH, 0.63. The excess of removal cellulose content with a high concentration of chemical treatment will damage the filler and increase the brittleness of composite hence decrease the impact strength due to restricted mobility of polymer chains [29].

![Figure 4: Effect of treatment on impact energy.](image)

4. Conclusions
In this research, the effect of chemical treatment on tensile and impact properties of bamboo filler reinforced recycled high-density polyethylene composites were investigated. It is clearly observed that both treatment either with alkaline (NaOH) or acidic (CH₃COOH) treatment improves the tensile properties. The 2.5 % NaOH treated BF / RHDPE composite has optimum tensile strength while CH₃COOH treated BF / RHDPE composite at 7.5%. As for impact strength, the optimum impact strength at 2.5 % of NaOH treated.
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