Mechanical properties of wood dust and recycled polymers blends composition in injection moulding

M.Z.Umor¹, A.Mohd¹*, M.Azwandy¹.

¹Faculty of Engineering Technology, University College TATI, 24000 Kemaman, Terengganu, Malaysia. Tel./Fax +6-09-8601000/+6-09-8635863

*Email: aliasmohd@uctati.edu.my

Abstract. Composites based on natural fiber reinforcement and recycled plastics blends has produced wide research and composites engineering interest in previous decades due to their high strength, small density, low cost, light in weight, recyclability and biodegradability as far as green technology is concerned. The tensile strength and water absorption were investigated at the different loading ratio. In this paper, wood dust, recycled Polyethylene Terephthalate, recycled Polyethylene (rPET/rPE) and SEBS-g-MA compatibilizer were processed with different wood dust loadings of 5, 10, and 15 wt %. In addition to molding process parameters such as the melt temperature and injection pressure will be considered which is influenced on part quality. From the observation it was indicates that the mechanical properties of tensile has increased with 15 wt % fiber whereas the water absorption also increased due to the hydrophilic nature of the filler.

1. Introduction

Process of recycling the plastics waste received worldwide attentions because it will reduce the manufacturing resources, conserves energy in production and reducing the pollution effect to the environment. Recycling of polymer material is very important because in most cases, it isn’t biodegradable and can accumulate in landfills for decades when the plastic waste is discarded. Wood particles provide high specific strength and modulus that allow the production of composites with higher filler content[1,2]. There are many methods developed to recycle PET (r-PET) wastes, for example mechanical recycling, chemical recycling process and recovery of energy. Mechanical recycling in r-PET, blending r-PET with other polymers is commonly effective method because easy to fabricate, economy and produce good mechanical properties of the blends. Oksman and Lindberg reported in their study that tensile strength of recycled PE/wood particle composites was improved with the addition of maleated styrene ethylene/butylene-styrene(SEBS-MA) triblock copolymer and reached its maximum level with 4 wt% SEBS-MA [3]. Compatibilizer widely used in plastic composite in order to improve the adhesion between fibers and matrix which effectively enhance the performance of composite [4]. Recycling activities of polyethylene is essential because in most cases, it isn’t biodegradable and can accumulate in landfills for decades. Because of its composition, the blends of plastic waste can be melted and reshaped as it solidifies, making it reusable. Recycled polyethylene used in this polymer blends is to improve the processing and retains the good thermal and mechanical properties. Therefore, blends prepared from virgin and/or recycled...
components become a well-established strategy to handle post consumer and post-industrial polymeric wastes. Cezary Gozdecki and Arnord Wilczynski reported about mechanical test (tensile strength) and physical (water absorption) properties of wood-plastic composites made from industrial wood particles used for manufacturing three layer particleboards and high-density polyethylene [5]. However, the mechanical properties of wood plastic composites actually are not sufficient to fit the requirements for structure and engineering construction. The reason is that the hydrophilic bio fibers and hydrophobic thermoplastic matrix normally creates a weak interfacial bonding [6, 7, 8]. Wood has been used by plastic industry as inexpensive filler to increase strength and stiffness of thermoplastic or to reduce raw material cost [9]. Most are the polymers are not compatible with each other, thus a suitable compatibilizer is required to achieve good miscibility between the phases. Wood dust used in this study is obtained from nearby saw mill industry. Previous study stated that the use of compatibilizer agent maybe increase the cost on recycled-based blending material product which probably reduces the interest of using recycled material [10]. Chen RS and Ahmad S studied the increment in tensile properties of the composite when the recycled polymer blend was reinforced with hybrid fillers compared to single fiber reinforcement. The properties then improved with the presence of compatibilizer [11].

2. Materials and Methodology

2.1 Materials

The materials used in this study were recycled Polyethylene Terephthalate (rPET) and recycled Polyethylene (rPE), as a polymer matrix; wood dust (WD) used as a filler and styrene/ethylene-butylene/styrene copolymer grafted with maleic anhydride (SEBS-g-MA), which were used as compatibilizer. The recycled Polyethylene Terephthalate (rPET) used in this study was selected from the wasted plastic drinking bottles. The bottle was drained in warm place to make sure the bottle dry completely. Then plastic crusher machine model VMM 5.5HP used for grinding the bottle to get crushed plastic bottle in granular form. Heavy duty blender model Venus TM-76711 1500W also used for getting smaller size before mixing in the blending ratio.

2.2 Chemical treatment

Wood dust obtained from saw mill treated with 10% Sodium Hydroxide (NaOH) solution. All the wood dust kept into solution for about two hours at room temperature. Then this wood dust separated from NaOH, washed with water for a few times before washed with distilled water. Wood dust that has been treated and washed goes for dry for about five hours in an oven to remove all the moisture content absorbed. Then wood dust particle has been sieved with size of 355 micron meter. The specific ratio of composition r-PET, rPE, wood dust and SEBS-g-MA are listed in Table 1.

| Designation | r-PET (wt%) | rPE (wt%) | Wood Dust | SEBS-g-MA |
|-------------|-------------|-----------|-----------|-----------|
| r-PETrPEWD5 | 15          | 75        | 5         | 5         |
| r-PETrPEWD10| 25          | 60        | 10        | 5         |
| r-PETrPEWD15| 35          | 45        | 15        | 5         |
2.3 Sample preparation
The compounding process was conducted according to the formulation in Table 1. Samples of r-PET, rPE, wood dust and SEBS-g-MA are measured by weight separately and then manually shaking to make sure all the materials were mixed well. The blends materials then injection molding following specimen dimension of American Standard Testing and Material (ASTM638) for tensile by using (TOYO 50 Ton) injection molding machine with range temperature of 170° -180° and injection pressure of 40 MPa.

2.4 Mechanical Test
The tensile test was carried out using three different filler content samples. The testing of tensile strength is performed by using tensile test machine (INSTRON) by following standard of ASTM D638. Each testing was performing until tensile failure occurred.

2.5 Water absorption
The samples soaked in distilled water at an average temperature of 24°C for 24 hours, 3 days and one week. The mean values recorded after each ratio blends experiment as shown in equation (1).

\[
\text{Formula for Water Absorption (\%) = } \frac{W^2 - W^1}{W^1} \times 100 \%
\]  

(1)

Where W\(^1\) is the weight of the dry sample and W\(^2\) is the weight of the sample after soaked.

3. Results and Discussion

3.1. Mechanical properties
Mechanical properties of polymer blends influenced by the ratio of composition, dimension and the physical properties of the components. The interfacial interaction between the components has given the important factors because it’s not only change the local deformation and micro mechanism of the local deformation and the breaking process, but also influence the crystalline behavior of the components, both of them has influence the mechanical properties of the composites.

Table below indicated the results of 5%,10% and 15% wood dust ratio.

| Wood Ratio (%) | Melting Temperature (°C) | Injection Pressure (MPa) | Tensile Strength (MPa) |
|----------------|--------------------------|--------------------------|------------------------|
| 5              | 170°-180°                | 40                       | 7.354                  |
| 5              | 170°-180°                | 40                       | 8.124                  |
| 5              | 170°-180°                | 40                       | 7.616                  |
| 5              | 170°-180°                | 40                       | 8.889                  |
| 5              | 170°-180°                | 40                       | 8.360                  |
| 5              | 170°-180°                | 40                       | 5.920                  |
| 5              | 170°-180°                | 40                       | 8.883                  |
| 5              | 170°-180°                | 40                       | 5.587                  |
| 5              | 170°-180°                | 40                       | 8.675                  |
| 5              | 170°-180°                | 40                       | 8.983                  |
Table 3. Tensile strength value for 10% wood dust

| Wood Ratio (%) | Melting Temperature (°C) | Injection Pressure (MPa) | Tensile Strength (MPa) |
|----------------|--------------------------|--------------------------|------------------------|
| 10             | 170°-180°                | 40                       | 9.071                  |
| 10             | 170°-180°                | 40                       | 7.490                  |
| 10             | 170°-180°                | 40                       | 8.030                  |
| 10             | 170°-180°                | 40                       | 8.399                  |
| 10             | 170°-180°                | 40                       | 8.607                  |
| 10             | 170°-180°                | 40                       | 9.705                  |
| 10             | 170°-180°                | 40                       | 7.038                  |
| 10             | 170°-180°                | 40                       | 8.309                  |
| 10             | 170°-180°                | 40                       | 9.997                  |
| 10             | 170°-180°                | 40                       | 8.156                  |

Table 4. Tensile strength value for 15% wood dust

| Wood Ratio (%) | Melting Temperature (°C) | Injection Pressure (MPa) | Tensile Strength (MPa) |
|----------------|--------------------------|--------------------------|------------------------|
| 15             | 170°-180°                | 40                       | 10.57                  |
| 15             | 170°-180°                | 40                       | 10.14                  |
| 15             | 170°-180°                | 40                       | 9.552                  |
| 15             | 170°-180°                | 40                       | 9.288                  |
| 15             | 170°-180°                | 40                       | 10.11                  |
| 15             | 170°-180°                | 40                       | 11.58                  |
| 15             | 170°-180°                | 40                       | 9.575                  |
| 15             | 170°-180°                | 40                       | 10.56                  |
| 15             | 170°-180°                | 40                       | 11.23                  |
| 15             | 170°-180°                | 40                       | 10.77                  |

The result indicated that average tensile strength of r-PET/rPE/SEBs with 5% wood dust contributes to 7.839, while 10% wood dust was 8.480 and the highest ratio of 15% wood dust achieved to 10.338.

3.2. Water Absorption
Based on the Table 5, the immersion data for 24 hours, 3 days and one week is compared to the initial weight for ten traits. Result of the diffusion rate after 1 week by using formula was 1.25, 2.54, 2.46, 2.33, 2.33, 2.25, 2.33, 1.19, 1.14 and 1.11%.
Table 5. Water absorption of 5% wood dust

| Traits | Initial weight (g) | 24 hours soaked (g) | 3 days soaked (g) | 1 week soaked (g) |
|--------|--------------------|---------------------|------------------|------------------|
| 1      | 8.3                | 8.3                 | 8.4              | 8.4              |
| 2      | 8.1                | 8.2                 | 8.3              | 8.3              |
| 3      | 8.6                | 8.7                 | 8.8              | 8.8              |
| 4      | 8.6                | 8.7                 | 8.7              | 8.8              |
| 5      | 8.6                | 8.7                 | 8.7              | 8.8              |
| 6      | 8.6                | 9.0                 | 9.0              | 9.1              |
| 7      | 8.6                | 8.7                 | 8.7              | 8.8              |
| 8      | 8.4                | 8.4                 | 8.5              | 8.5              |
| 9      | 8.8                | 8.8                 | 8.9              | 8.9              |
| 10     | 9.0                | 9.0                 | 9.1              | 9.1              |

According to the Table 6, the immersion data for 24 hours, 3 days and one week is compared to the initial weight for ten traits. Result of the diffusion rate after 1 week by using formula for 10% wood dust was 4.44, 3.09, 5.32, 4.35, 5.26, 5.20, 4.21, 4.35, 4.30, and 4.24%.

Table 6. Water absorption of 10% wood dust

| Traits | Initial weight (g) | 24 hours soaked (g) | 3 days soaked (g) | 1 week soaked (g) |
|--------|--------------------|---------------------|------------------|------------------|
| 1      | 9.0                | 9.1                 | 9.2              | 9.4              |
| 2      | 9.7                | 9.8                 | 9.9              | 10.1             |
| 3      | 9.4                | 9.5                 | 9.7              | 9.9              |
| 4      | 9.2                | 9.3                 | 9.4              | 9.6              |
| 5      | 9.5                | 9.6                 | 9.7              | 10.0             |
| 6      | 9.6                | 9.7                 | 9.9              | 10.1             |
| 7      | 9.5                | 9.6                 | 9.7              | 9.9              |
| 8      | 9.7                | 9.8                 | 9.9              | 10.1             |
| 9      | 9.2                | 9.3                 | 9.4              | 9.6              |
| 10     | 9.3                | 9.4                 | 9.5              | 9.7              |

Meanwhile on the Table 7, the immersion data for 24 hours, 3 days and one week is compared to the initial weight for ten traits. Result of the diffusion rate after 1 week by using formula was 7.52, 7.87, 8.79, 7.77, 6.59, 5.49, 6.74, 7.61, 7.80, 7.29%. According to the three data of water absorption to the ratio of wood dust, it’s showed that 5% wood dust resulted the diffusion rate average of 8.75%, while 10% wood dust contributed to 9.76%. For the 15% wood dust ratio, it’s showed the value of 9.82%.

Table 7: Water absorption of 15% wood dust

| Traits | Initial weight (g) | 24 hours soaked (g) | 3 days soaked (g) | 1 week soaked (g) |
|--------|--------------------|---------------------|------------------|------------------|
| 1      | 9.3                | 9.4                 | 9.7              | 10.0             |
| 2      | 8.9                | 9.1                 | 9.3              | 9.6              |
| 3      | 9.1                | 9.3                 | 9.5              | 9.9              |
| 4      | 9.0                | 9.2                 | 9.5              | 9.7              |
| 5      | 9.1                | 9.1                 | 9.3              | 9.7              |
| 6      | 9.1                | 9.2                 | 9.4              | 9.6              |
| 7      | 8.9                | 9.0                 | 9.2              | 9.5              |
| 8      | 9.2                | 9.3                 | 9.6              | 9.9              |
| 9      | 9.0                | 9.1                 | 9.3              | 9.7              |
| 10     | 9.6                | 9.7                 | 10.0             | 10.3             |
4. Conclusion
The use of recycled PET (plastic bottles), wood dust and recycled PE in this study is achieved in the effort of reducing the plastic wastes pollution. Material of recycled PE blends with recycled PET helps in the injection molding processing due to the recycled PET has the slow rate of crystallization which is difficult to control the processing parameter. The mechanical property of tensile strength with wood dust is studied under the three fillers content. The wood dust consists good filler characteristics as it improves the strength of the polymeric resin. It is recommended for the further study to increase the ratio of recycled PET, PE/or other plastic material and natural fiber to the products selected which is not critical consideration in the properties water absorption such as interior parts of automobiles. Blends composition of different recycled plastic material with natural fiber helps the researcher to find the new plastic composites product. Due to the additional cost of process separation recycled plastics, it is recommended that compositions of recycled plastic blends are used together for the new wood plastic composites product.

5. References

[1] Ashori A, Nourbakhsh A 2010 Compos Part B: Eng;41(7):578–81.
[2] Liu W, Drzal LT, Mohanty AK, Misra M. 2007 Compos Part B: Eng;38(3):352–9.
[3] Oksman K, Lindberg H. 1998 J Appl Polym Sci; 68:1845–55.
[4] Selke SE, Wichman I. 2004 Wood fiber/polyolefin composites. Compos Part A;35:321–6.
[5] Cezary Gostdecki, Arnold Wilczynski 2015 Effect of Wood Particle Size And Test Specimen Size on Mechanical and Water Resistance Properties of Injected Wood-High Density Polyethylene Composite.
[6] Lai S M, Yeh F C, Wang Y, Chan H C, Shen H F 2003 Journal of Applied Polymer Science 87 (3): pp. 487–496.
[7] Choi M H, Jeon, B. H., Chung, I. J 2000 Polymer 41 (9): pp. 3243–3252.
[8] Rose I M D, Marra F, Pulci G, Santulli C, Sarasini F, Tirillo J, Valente M 2012 Applied Composites Materials19 (3–4): pp. 475–490.
[9] Endra Gunawan, AnomIndra Adhyaksa and Reinardus L. Cabuy. 2012 Influence of Sawdust Size and Ratio of HDPE Waste on The Physical Properties of Wood-Plastics Composite.
[10] Strapasson R, Amico SC, Pereira MFR, Sydenstricker THD 2005 Polym Test ;24(4):468–73.
[11] Chen RS, Ahmad S. 2017 Mater Chem Phys;198:57–65.