Characteristics of recycled HDPE/bamboo fibre composite

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Abstract. Increasing the mechanical properties of recycling can be done by adding natural fibers into composite materials. The focus of this research is to develop a composite using bamboo as a reinforcing material and recycled High Density Polyethylene (HDPE) as a matrix using the extrusion method. This study aims to analyze the mechanical analysis between bamboo fiber-based composites using a pure HDPE matrix and composites using recycled HDPE matrices at a matrix volume fraction: 70% 30% fiber. Mechanical tests were performed using the tensile testing machine model RAY-RAN Test Equipment M500-50CT with ASTM D 638 standards to evaluate the tensile strength and modulus of the composite. The results showed that the tensile strength and Young's modulus of bamboo fiber reinforced rHDPE composites were 8.764 MPa and 52.0152 MPa, respectively. While the bamboo composite with a vHDPE matrix has a tensile strength of 9.3312 MPa and a Young's Modulus value of 94.8468 MPa. Thus, bamboo fiber reinforced composites with pure HDPE matrix have better mechanical properties than bamboo composites with recycled HDPE matrices. Differences in matrix shape can affect composites resulting from such fibers.

Keyword: Bamboo Fiber, recycled High Density Polyethylene (rHDPE), virgin High Density Polyethylene (vHDPE), Mechanical Properties

1. Introduction

Composites are materials consisting of two or more materials with the characteristics of lightweight, stiffness, corrosion resistance and ductility. Polymer composites have an important role in human life. The fibers used as polymer matrix reinforcement can be synthetic or natural fibers [1]. Meanwhile, the matrix used is one of the types of commercial polymers such as High-Density Polyethylene (HDPE). HDPE has a high density level, is flexible, resistant to impact, and chemicals at a relatively low price [2]. Callister in Lins et al. [3] states that HDPE has a low modulus and low strength, with around 1 GPa each and between 22 MPa to 33 MPa.

Mancini in Reis et al. [4] states that the total composition of HDPE waste in Brazil is in second place after Polyethylene Terephthalate (PET) with about 30% of the total collected rigid plastic. Jambeck [5] states that of the 192 countries studied, Indonesia is in second place after China with the amount of plastic waste reaching 187.2 million tons. Plastic waste is currently a major problem in landfills (TPA). Lack of municipal waste management can result in improper disposal and clogging of drains which can lead to flooding, the spread of disease and environmental pollution. The very low utilization of HDPE and the high amount of plastic waste causes widespread waste and shortens the life of landfills. Therefore, the study of municipal waste for recycling is very important for the community. Reis et al. [4] studied a one-dimensional phenomenological damage model to describe the viscoelastic behavior of recycled HDPE in tensile tests.
for different strain levels. The mechanical properties of recycled HDPE can be improved by developing and acting as a natural fiber reinforced composite matrix.

One of the potential natural fibers is bamboo fiber. Abdul Khalil [6] shows that the types of bamboo in the world reach 1200-1300 species with 11.9% of these species in Indonesia. According to Viel in Refiadi et al. [7] petung bamboo is the most common bamboo found in Java and Sumatra with a fiber diameter of about 195-361 mm, has tensile strength between 114-314 MPa, modulus range of elasticity 3, 2-7 GPa and the strain is between 3.3-5.1%. Osorio L in Wang et al [8] states that bamboo fibers have a strength comparable to glass fibers. So the use of bamboo as a natural fiber has the potential to strengthen the polymer matrix. Seeing the potential of bamboo fiber in recycled plastic composites, this research focuses on developing recycled bamboo and HDPE composites.

Reffiadi [7] found that the use of 5% NaOH solution is the optimum condition for alkalization of petung bamboo fibers which is capable of producing 384 MPa of tensile strength, 390.5 MPa of characteristic strength, and 175.098 ± 58.017 mm diameter fibers. Mohanty [9] found that the use of bamboo fibers can strengthen the HDPE matrix. Ren, et al. [10] showed that the mechanical properties of HDPE polymer composites with Bamboo Pulp Fibers (BPF) of 30% by volume had better mechanical strength, modulus and thermal stability than the use of 50% Bamboo Fibers (BF) in composites.

Research on the use of rHDPE (recycled HDPE) as a composite matrix with bamboo fiber reinforcement has not been widely carried out. For this reason, this study aims to determine whether there are differences in mechanical properties between bamboo fiber reinforced composites using pure HDPE matrix and composites using recycled HDPE matrices.

2. Material and Methods

2.1 Tools and Materials

The extrusion machine used for the manufacture of composite specimens is equipped with four heaters, with temperatures between 160 °C and 175 °C. The bamboo fiber used in this study is a type of petung bamboo which is cut lengthwise and chopped into 5 mesh sizes. The matrix used is the vHDPE matrix which is a pure plastic material and rHDPE comes from recycled plastic which is chopped into 5 mesh sizes. NaOH solution is a solution used in the alkalization process as much as 5% to reduce the moisture content in bamboo fibers.

2.2 Physical Treatment

The vHDPE matrix used has the form of a plastic pellet. Meanwhile, the rHDPE to be used is in the form of shredded HDPE plastic packaging by sorting rHDPE from other plastic types. In order to obtain clean conditions, rHDPE is washed and then dried under the direct sun. After it is clean and dry, then the chopping process is carried out with a crusher machine to form 5 mesh chunks. Bamboo used is a type of bamboo petung with an age range of 3 to 4 years. The bamboo is cut 30 cm long with a saw. After being cut, the bamboo is beaten until crushed and the fibers separate from the lignin macro from one another, then soaked in 5% NaOH solution for 2 hours to reduce the lignin content and washed thoroughly with water, then dried for 12 hours at 60 °C in an oven until the water content is less than 2% [10]. After drying, the bamboo fibers are chopped using a crusher and sieved into 5 mesh sizes.

2.3 Specimens Preparation

The first step in making the specimen is to weigh the matrix material and bamboo fibers according to the matrix composition: fibers at 70%; 30% volume fraction. The mixture of polymer resin and bamboo fiber is put into an extruder with a heater temperature setting of 160, 165, 175 and 175 °C [10]. Furthermore, the product produced by the extruder is cooled to room temperature and cut to the size of the test.
2.4 Mechanical Testing

Test specimens are cut according to ASTM D 638 standard for tensile testing. The specimens were formed into dog bone with dimensions of $63.5 \times 9.53 \times 3.18$ mm and totaled 5 specimens. Ray-Ran Test Equipment M500-50CT is used for tensile strength tests. The following is an equation of tensile strength and modulus of elasticity:

\[
\sigma = \frac{F}{A} \quad (1)
\]

\[
E = \frac{\sigma}{\epsilon} \quad (2)
\]

where $\sigma$ is tensile strength (MPa), $F$ is load (N), $A$ is cross-sectional area (mm$^2$), $E$ is modulus of elasticity (MPa), $\epsilon$ is strain. Tensile strength and modulus of elasticity are measured from an average of 5 (five) specimens.

3. Result and Discussion

3.1 Mechanical Properties

The tensile test is carried out at room temperature according to ASTM D638. In this study, all tensile specimens were withdrawn at a speed of 50 mm/min. Before testing the thickness of the test object, it is measured first using a caliper. The test is stiffened five times per variation and the tensile strength is averaged. Table 1 shows the results of the tensile strength testing of the composite specimens.

| Sample | Tensile Strength (MPa) |  | Young Modulus (MPa) |  |
|--------|------------------------|--------|---------------------|--------|
|        | rHDPE / Bamboo Fiber | vHDPE / Bamboo Fiber | rHDPE / Bamboo Fiber | vHDPE / Bamboo Fiber |
| 1      | 8,321                  | 9,314  | 34,925              | 96,393 |
| 2      | 8,478                  | 9,333  | 49,224              | 86,452 |
| 3      | 9,198                  | 9,349  | 56,66               | 88,887 |
| 4      | 7,553                  | 8,632  | 54,346              | 103,824|
| 5      | 10,27                  | 10,028 | 64,921              | 98,678 |
| Average| 8,764                  | 9,312  | 52,0152             | 94,8468|
| Standard Deviation | 1,025 | 0,494 | 11,107 | 7,135 |
Figure 3. Tensile Strength and Young's Modulus

Figure 4. Tensile Strength vHDPE / Bamboo Fiber

Figure 5. Tensile Strength rHDPE / Bamboo Fiber
In Table 1, it is observed that the tensile strength and modulus of young rHDPE composite with bamboo fiber reinforcement are 8.764 MPa and 52.0152 MPa, respectively. Whereas in the composite with the vHDPE matrix, the tensile strength and modulus young were 9.3312 MPa and 94.8468 MPa, respectively. From Figure 3, it can be seen clearly that bamboo fiber composites with a vHDPE matrix have greater strength and tensile modulus than rHDPE. In addition, Figures 4 and 5 show that the vHDPE matrix has lower ductility than rHDPE, but yHDPE has a better tensile strength value. The results of this study support the findings made by Lu and Oza [11] who examined HDPE matrices with hemp fibers. In this study, the mechanical properties of composites with a vHDPE matrix were better than those of the rHDPE matrix. The use of the polymer matrix has different shapes such as the rHDPE matrix in the form of flakes or flakes, while the form of the vHDPE matrix is in the form of granules. The difference in the shape of the matrix will cause the clumping of bamboo fibers in a small number of binding matrices. This will have a negative effect that limits the tensile strength [12]. In addition, it will cause the separation of compatibility in the binder, and an increase in the level of debonding between the matrix and the reinforcing material [13]. So that composites with virgin polymer matrices have better performance than recycled matrices. Differences in matrix shape can affect composites resulting from such fibers.

4. Conclusion

The conclusion from this research is that the composite with virgin polymer matrix has a better performance than the recycled matrix with the average tensile strength and modulus values are 9.3312 MPa and 94.8468 MPa. To know the material structure in more detail on the difference in mechanical properties between vHDPE and rHDPE based composites, SEM analysis is needed. Further analysis in evaluating differences in the physical properties and structure of composites is to test their thermal properties. Thus, a complete picture will be obtained of the differences in the characteristics of composites produced using recycled polymer matrices and pure polymers.

5. References

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