MECHANICAL PROPERTIES OF BAMBOO ON VIRGIN AND RECYCLED HIGH-DENSITY POLYETHYLENE MATRIX

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Abstract. Natural fiber-reinforced polymer composites are considered to have advantages over synthetic fibers, namely that they are more environmentally friendly but with better mechanical properties. The purpose of this study was to make a pure / recycled HDPE (High-Density Polyethylene) composite with bamboo fiber reinforcement by analyzing the mechanical properties of the composite. The method used in this research is experimental with a quantitative approach. Experiments are carried out by creating or manipulating certain conditions and by providing control over the test specimen. Pure / recycled HDPE plastics and bamboo fibers will be mixed in a machine extrusion molding with a temperature heater (160, 165, 170, 175) ° C. Before fabrication, bamboo fibers are treated with alkaline treatment, namely by immersing 5% NaOH. The ratio of mass fraction between vHDPE/rHDPE and bamboo fiber was 70%: 30%. This study evaluated the mechanical properties of HDPE-bamboo composites using Izod Impact testing with ASTM D 256-05 standards. Tests were carried out to analyze the differences between pure HDPE and recycled HDPE matrices on bamboo fiber reinforced composites. The mechanical test results showed that the impact strength on bamboo composites with recycled HDPE matrix was 2.69 (KJ / m²) while bamboo composites with pure HDPE matrices had an impact strength of 1.6 (KJ / m²). Thus, the mechanical properties measured by impact strength on composites with recycled HDPE matrices were better than composites with pure HDPE matrices. In accordance with the results of research that has been done, recycled HDPE can be used as a matrix composite with mechanical properties that are not too different from composites with pure HDPE matrices. This can be done as a means of utilizing recycled HDPE waste instead of pure HDPE.

1. INTRODUCTION

Natural fiber reinforced polymer composites are increasingly in demand in the fabrication, automotive, construction and building industries with applications ranging from household appliances to the industrial sector. Natural fiber reinforced polymer composites have advantages over synthetic fibers especially in low cost, low density, high strength, high stiffness, good absorbency and high energy absorption [1]. This is one of the factors in the development of natural fiber reinforced composite materials.

Recycled plastic composites (recycled) with natural fibers is an innovative material development to reduce the amount of plastic waste and the use of environmentally friendly natural fibers. In a study conducted by Jambeck [2], of the 192 countries studied, Indonesia was in second place after China, with the amount of plastic waste reaching 187.2 million tons. Plastic waste is a type of waste that cannot be decomposed by decomposing microorganisms. To overcome this, it requires efforts that aim to utilize plastic waste. Making recycled plastic composites with the addition of bamboo fibers is one way to solve the problem of plastic waste.

Several previous studies have developed natural fiber reinforced polymer composites with recycled polymers (High Density Polyethylene) as a matrix. Wirawan et al. [3] analyzed the thermal stability of water hyacinth composites using an HDPE matrix, this study found that the thermal stability of the composites decreased along with the increase in water hyacinth fiber content and the increase in thermal
stability with alkaline treatment where the increase in thermal stability was obtained by the addition of NaOH concentration. Ren, et al. [4] showed that the mechanical properties of HDPE polymer composites with Bamboo Pulp Fibers 30\% (BPF) have better mechanical strength, modulus and thermal stability than 50\% Bamboo Fibers (BF). The development of recycled HDPE (rice husk composite matrix recycled high-density polyethylene) by Rajendran Royan, Sulong, and Yohana [5] found that the composites were sensitive to cracks.

Many researches on the use of bamboo fibers as reinforcement for composite materials have been carried out. Irianto [6] conducted research on the effect of bamboo fibers on the impact strength of bamboo fiber composites, the test results obtained that the impact strength with a volume fraction of 30\% was 0.047 J / mm², a volume fraction of 40\% was 0.073 J / mm² and a volume fraction of 50\% is 0.119 J / mm² from these results, bamboo fiber composites have the potential to be developed for technical materials [7]. From the research results above, bamboo fibers can be used as a reinforcement for composite materials, mechanical properties testing will be carried out in this study.

Seeing the potential of bamboo fibers as reinforcement in polymer matrices, this study focuses on developing bamboo fiber-based composites using recycled HDPE matrices. The purpose of this study was to evaluate the mechanical properties by comparing the impact strength of bamboo fiber reinforced composites using a pure HDPE matrix and a recycled HDPE matrix. Materials with high impact strength will have a material toughness against high shock loads making them suitable for the manufacture of composite materials. This research is expected to increase knowledge in developing the use of natural fibers, namely bamboo fibers as a composite reinforcing material.

2. MATERIAL AND METHODS

2.1 Material

Materials used in this study are pure / recycled HDPE as a matrix material and bamboo fibers as the binder. Recycled HDPE is obtained from waste in plastic waste storage. Before processing the recycled HDPE composites, they are cleaned from the dirt sticking to the plastic and dried under the sun. The bamboo used in this study was petung bamboo with ages ranging from 3-4 years. The part of the petung bamboo used is the skin of the bamboo and the middle of the bamboo.

2.2 Prepare a Matrix of HDPE

Recycled HDPE plastic and pure HDPE that is clean and dry, the next step is to chop recycled and pure HDPE plastic by using a machine Crusier to form smaller flakes, approximately 5 size mesh in.

2.3 Preparing Bamboo fibers

Fibers used in this study are petung bamboo which is about 3-4 years old. The part of the bamboo taken is the skin of the bamboo and the middle of the bamboo. Then the bamboo that has been cut is beaten until it becomes crushed and the fibers on the bamboo are separated from the lignin. The next process is washing the bamboo fibers with clean water, then drying the clean bamboo fibers using an oven at a temperature of 60°C in about 12 hours. The dried bamboo fibers are then chopped into smaller sizes using a machine Crusier, until the bamboo fiber size is approximately 5 mesh.
2.4 Making a Sample

Mold This mold is made according to the composite sample to be tested. Testing the mechanical properties of the impact using a mold with a rectangular shape. The composite sample for the impact test was the sample was rectangular with dimensions (~ 63.5 × 12.7 × 3.17 mm) and weighed 1.5 g. Both sample types were tested on the Instron POE 2000 using impulse data acquisition software.

2.5 Physical Treatment

Bamboo that has been cut, beaten until crushed and the bamboo fibers are macro-separated with their lignin from one another. The bamboo fibers that have been crushed are then subjected to Alkali treatment by soaking the bamboo fibers in 5% NaOH solution for 1 hour to reduce the chemical content in the bamboo fibers, after the Alkali treatment, the bamboo fibers are immersed using a dispersion agent, namely stearic acid, the use of stearic acid used to reduce the natural hydrophilicity of the fiber to obtain a good bamboo fiber [8]. The bamboo fibers are washed with clean water, dried in an oven at 60% for approximately 12 hours. The bamboo fibers that have been dry are chopped with a size of approximately 5 mesh using a crusher machine.

2.6 Specimens Preparation

The process of making bamboo fiber HDPE composite specimens by weighing the weight of pure / recycled HDPE and bamboo fiber with a volume fraction ratio of 70: 30% using digital scales. First install the composite specimen mold on the end of the nozzle first. Heating the barrel temperature in the extrusion machine by varying the temperature of each barrel zone, namely 75, 110, 120, and 140°C, after the hot barrel is inserted a mixture of composition between pure / recycled HDPE chopped and chopped bamboo fiber into the hopper of the machine Extrusion Molding. The difference in temperature variations in the barrels is intended to regulate the melting point of the polymer and bamboo fibers so that they can combine into one material composition and form a bamboo fiber reinforced polymer composite. The speed screw barrel used ranges from 110 to 150 Rpm. The results from the machine Extrusion Molding will go directly to the mold at the end of the nozzle then cooled down to room temperature.

![Figure 1. rHDPE / Bamboo Fiber Composite](image-url)
Figure 2. vHDPE / Bamboo Fiber Composite

2.7 Mechanical Testing

The impact test specimen was removed from the mold and formed into a rectangle in the dimensions of 63.5 × 12.7 × 3.17 mm. Testing is done using the Izod method. Five samples were tested according to the ASTM D 256-05 procedure to determine the angle β.

\[ W = G \times \lambda \left( \cos \beta - \cos \lambda \right) \text{(J)} \]  \hspace{1cm} (1)

\[ K = \frac{W A_0}{A} \]  \hspace{1cm} (2)

Where W1 is the work done (kg / m) and W2 is the remaining work after breaking the test object (J), while W is the effort required to break the test object (J). After the work value is obtained, to find K the value of the impact strength (KJ / m²) is the work required W divided by the cross-sectional area A₀ (mm²).

3. RESULT

3.1 Mechanical Properties

The method of treating the mechanical properties of pure and recycled bamboo fiber-reinforced HDPE composite materials aims to determine the impact strength of recycled polymer composites reinforced with bamboo fibers against shock loads or sudden loads received by the material by calculating the energy required, given the load and calculate the energy received by the material to the maximum limit using the method Izod [9]. Table 1 and Figure 1 show that the sample in the recycled HDPE composite has the energy required to split the sample with an average of 0.10782 J and has an impact strength value of 2.69 (KJ / m²) while the virgin HDPE composite has the energy needed to split the sample. with an average of 0.06434 J and an impact strength value of 1.6 (KJ / m²). So, the results of this impact test show that the impact strength of the recycled HDPE specimen has a higher value than the virgin HDPE specimen.

| Sample | rHDPE | vHDPE | rHDPE | vHDPE | KJ / m² rHDPE | vHDPE |
|--------|-------|-------|-------|-------|--------------|-------|
| 1      | 126.9 ° | 130.1 ° | 0.09241 | 0.05456 | 2.31         | 1.36  |
| 2      | 126.9 ° | 129.5 ° | 0.09241 | 0.06157 | 2.31         | 1.53  |
| 3      | 125.8 ° | 129.5 ° | 0.10583 | 0.06157 | 2.64         | 1.53  |
| 4      | 125.1 ° | 129 °  | 0.11444 | 0.06738 | 2.86         | 1.68  |
| 5      | 123.5 ° | 128.2 ° | 0.13441 | 0.07682 | 3.36         | 1.92  |
| Average|       |       |       |       | 2.69         | 1.6   |
| Standard Deviation |       |       |       |       | 0.43844 | 0.209833 |
Research by Lu & Oza [1], on the comparison of the mechanical properties of recycled HDPE and virgin HDPE composites reinforced with hemp fiber with a volume fraction of 30%. The results of this study indicated that the impact strength of hemp-recycled HDPE had a higher value than the hemp-virgin HDPE composite. From the results of this impact test, it can be seen from the fracture mechanics, crack propagation and the interaction between the fiber and matrix that the impact strength of recycled HDPE is slightly higher than that of virgin HDPE.

Oza, Lu, & Korman [10] research on hemp fiber composites with a matrix mixing of virgin HDPE and recycled HDPE showed a fiber volume fraction of 30% gave the highest impact strength between virgin HDPE and recycled HDPE. The impact strength of composites with recycled HDPE was slightly higher than virgin HDPE due to impurities in the recycled HDPE matrix compared to virgin HDPE. The maximum strength obtained with the recycled HDPE composite was 51.1 (KJ / m²) and virgin HDPE was 42.50 (KJ / m²).

The results of the impact test in this study show the similarity of the results with research conducted by Lu & Oza [1] and Oza, Lu, & Korman [10]. The results of this study indicate that the Izod impact test on HDPE-bamboo recycled composites has a higher impact strength value than virgin HDPE-bamboo composites. This can be seen from the fracture mechanics, crack propagation, the interaction between the fibers and the matrix and because of the impurities in the recycled HDPE matrix which makes the impact strength higher. In accordance with the results of research that has been done, recycled HDPE can be used as a matrix composite with mechanical properties that are not too different from composites with pure HDPE matrices. This can be done as a means of utilizing recycled HDPE waste instead of pure HDPE.

4. CONCLUSION

Recycled HDPE composites with bamboo fiber reinforcement is one of the polymer composites of concern recently due to its biodegradable nature. The combination of polymer matrix with natural fiber reinforcement such as bamboo has been applied in various industrial sectors due to its superiority in providing the required combination of mechanical properties. However, the combination of polymers and natural fibers can also provide disadvantages due to the different properties of each constituent.

In this study, a comparison of pure HDPE and recycled HDPE was carried out with bamboo fiber reinforcement to determine the mechanical properties and toughness of the material against shock loads. After testing, it can be seen that the impact strength of recycled HDPE bamboo fiber reinforced composites has a higher impact strength than pure HDPE bamboo fiber reinforcement.

5. REFERENCES

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