The Effect of Heating Variations on the Mechanical Strength of Hyacinth Fibers

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Abstract. Composite properties are determined by the properties of the fiber, matrix, and bonds formed between the fiber and the matrix. Improvement of fiber properties can be done by heat treatment. The effect of heating temperature on the mechanical strength of single water hyacinth fibers is the subject of this study. This study aimed to investigate the effect of heating temperature variations on the mechanical strength of a single water hyacinth fiber. The manufacture of water hyacinth fiber specimens refers to ASTM C1557. The research method used involved heating water hyacinth fibers at various temperatures, namely 60, 80, 100, and 120°C for 60 minutes each. These fibers are heated in the oven at these temperature variations, and then tested for mechanical strength. The data obtained is used to analyze the effect of heating temperature variations on water hyacinth mechanical fiber strength. The results showed that heating significantly affected the mechanical strength of water hyacinth fibers. The tensile strength of water hyacinth fiber continued to increase at heat treatment up to 100°C and decreased at above heat treatment. This research contributes to the development of better and more sustainable configurations of natural fibers.

1 Introduction

The use of natural materials in composite applications has become a major focus in efforts to create sustainable and environmentally friendly solutions [1]. In this context, single-fiber water hyacinth appears as a promising composite reinforcement material [2][3][4]. Water hyacinth (Eichhornia crassipes) is an aquatic plant that grows in abundance in tropical and subtropical waters around the world [5]. Fiber from water hyacinth has an interesting mechanical property, namely its relatively high tensile strength [6]. The cellulose content of water hyacinth is also large, at 72.63% [7]. Other advantages of water hyacinth fiber include low production costs, an environmentally friendly process, and always available or renewable; [8].

Many things affect the performance of composites, one of which is the bond between the fiber and the matrix. Natural fibers have hydrophilic properties, and polymers have hydrophobic properties [9]. This results in invalid bonds that occur between the fiber and the matrix. If the bond is weak, the mechanical properties of the composite will be low [10]. The bond between the fiber and the matrix can be increased by repairing the bond. This is by the statement [11][12][13] who said that the compatibility between the fiber and the polymer matrix can be improved by fiber modification, matrix modification, or the addition of a coupling agent. Heat treatment of fiber is one of the methods to improve fiber properties [14]. Heat treatment of the fiber aims to reduce the water content in the fiber to increase strength and improve the interfacial bond between the fiber and the matrix [15]. In this study, researchers used the oven method to heat water hyacinth single fibers at various predetermined temperatures. Heating at different temperatures can change the crystal structure of the fiber which in turn affects the mechanical strength of the fiber [16]. Another advantage of heat treatment is that it is environmentally friendly because it does not use chemicals that can cause environmental pollution [17].

Many studies have been carried out on the effect of heat treatment on natural fibers [18][19][20][21][22] but research on the impact of heat treatment on water hyacinth fiber has never been done. This research examines how variations in heating temperature affect the mechanical properties of single water hyacinth fibers.

The knowledge gained from this research has important implications for developing water hyacinths single-fiber applications in various fields, such as the construction, automotive, and composite materials industries. In addition, by using sustainable natural materials such as water hyacinths, we can reduce our dependence on non-recycled raw materials and reduce our negative impact on the environment. This paper will discuss the effect of variations in heating treatment on

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2 Methods

2.1 Materials

The dried water hyacinth fiber was obtained from the Lake Rawa Pening area, Ambarawa, Central Java, Indonesia. The components contained in water hyacinth consist of 72.63% cellulose, 8% hemicellulose, and 17% lignin.

2.2 Fiber Treatment

The research began with the preparation of water hyacinth fiber. The dried water hyacinth stems are then extracted to get the fiber using a fine wire brush. After the wool is extracted, it is then heated at 60°C for 1 hour to remove residual stress. This study examined water hyacinth fiber without heating and heating at various temperatures of 60, 80, 100, and 120°C for 1 hour using a Modena brand oven with a temperature capacity of 0-250°C and 1°C accuracy.

2.3 Specimen Making

 Manufacture of single fiber specimens according to ASTM C1557. Water hyacinth fiber is placed on cardboard with a length of 60 mm and a width of 10 mm. In the center of the cardboard, make a hole with a hole punch. The fibers are glued to the cardboard at both ends using epoxy glue. Fiber diameter was measured at three different points using a stereo microscope. Tensile test specimens can be seen in Figure 1.

2.4 Specimen Testing

The single fiber tensile test was carried out according to procedure ASTM C1557. The test used the JTM-UTS 510 Universal Testing Machine (UTM) with a cross head speed of 2 mm/minute, and a load cell used of 10 kg. Tensile mechanical strength: 30 samples were taken from each variation. Density testing was carried out with an ACIS B-5000 digital balance with a maximum capacity of 500 grams.

3 Result and Discussion

Figure 2 shows a graph of the increase in the tensile stress of water hyacinth fibers up to 100°C and then decreases at 120°C. In the heat treatment with a temperature of 100°C, water hyacinth fibers reached the highest tensile stress, namely 358.86 MPa. The increase in tensile stress at each increase in temperature is because the fiber undergoes structural improvements as the heating temperature increases. The progress of the structure occurs because the amorphous structure decreases, causing the crystal structure to increase. In the heat treatment with a temperature of 60°C, the fiber experienced a reduction in the water content on its surface. In the heat treatment of wool with a temperature of 80°C to 120°C the tensile stress has increased, this phenomenon is predicted to increase the crystallinity index (CrI). The increased CrI indicates an improvement in the cellulose structure, which contributes to increasing the tensile stress of the fiber. This is by research [23], which said that the crystallinity index (CrI) on the heat treatment of the fiber can be increased. A study [24] also suggested that the increase in crystallinity in cellulose after heat treatment was caused by the degradation of the amorphous structure in the fiber resulting in a rearrangement of the crystal structure.

The tensile stress of a single water hyacinth fiber decreased at a heat treatment temperature of 120°C. In the heat treatment of 120°C, the tensile stress value was 331.08 MPa. The tensile stress has decreased because the water bound to the lumen is predicted to experience evaporation, causing cavities in the fiber. This results in reduced fiber density. This is also by the statement [25] that heat treatment at high temperatures makes natural fibers brittle because the moisture in the fibers is much reduced.
Figure 3 shows an increase in the density of water hyacinth fiber starting from the variation without heating (1.205 gr/cm³) which has the lowest density value to the 100°C heating variation which has the highest density value (1.218 gr/cm³). This phenomenon is due to the recrystallization that occurs along with the increase in temperature in water hyacinth fibers. Recrystallization makes the structure of the molecules or crystals inside the fiber change and move to achieve a more regular/stable structure. This can occur due to heating or heat treatment of the fiber, which stimulates changes in the molecular bonding and crystal arrangement [26]. This process changes the fiber structure and leads to a reduction in porosity and an increase in density. Heating to a temperature of 120°C causes the fiber to experience a slight decrease in density from 1.218 gr/cm³ to 1.216 gr/cm³. This decrease is possible because the hemicellulose in water hyacinth fiber begins to break down. Hemicellulose consists of shorter polysaccharide chains, and its branches are more irregular than the longer and straighter structures of cellulose fibers. Due to its more labile structure, hemicellulose is more susceptible to environmental influences such as moisture and heat treatment [27].

Heating can remove some of the moisture trapped in the fiber, which can reduce the negative effect moisture has on the elasticity of the fiber [28]. As shown in Figure 4, the modulus of elasticity of water hyacinth fiber increased with increasing heating temperature. In this study, the highest modulus of elasticity was obtained from the 100°C heating variation, which was 9.997 GPa. In addition, the heating variation with a temperature of 100°C has the lowest strain value when compared to other variations, namely 8.58%, as shown in Figure 5.

Heating the fiber helps remove surface dirt so that the fiber looks smoother, as shown in Figure 6. Figure 7 shows the appearance of the fiber that has not received heat treatment. The fiber in Figure 7 has a rougher-looking surface. Fiber surfaces that have less dirt on their surface tend to have higher mechanical strength. This is by the statement [29] that the heat treatment of the fiber makes the fiber surface cleaner due to the loss of impurities such as wax.

4 Conclusion

Based on the research results, it can be concluded that the heating treatment of the fibers resulted in an increase in the mechanical strength of the fibers up to a temperature of 100°C and then decreased at the temperature above.

References


