Effect of fiber volume fraction on tensile strength and fracture analysis of corn husk reinforced epoxy resin composite

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Abstract. This study aims to determine the effect of volume fraction of corn husk fiber as reinforcement in epoxy matrix composites on tensile strength and fracture analysis of specimens. This study used a variation of fiber volume fraction of 20%, 30%, 40%, 50% by using the Vacuum Assisted Resin Infusion (VARI) method. Tensile testing and analysis of fracture patterns were carried out to determine the mechanical properties of the material. The results showed that the addition of corn husk fiber volume fraction to the corn husk reinforced epoxy resin composite could increase the tensile strength value. Tensile strength values for fiber length of 165 mm with variations in fiber volume fraction 20%, 30%, 40%, and 50% get the tensile stress values of 26.16 N/mm2, 27.09 N/mm2, 27.82 N/mm2, and 30.61 N/mm2. The mechanism of fiber pull out, debonding, and the rich matrix also occurs in the microstructure analysis of the tensile test fracture results.

Keywords. Volume fraction of corn husk fiber, VARI), Tensile strength, Fracture analysis

1 Introduction

Along with the development of industry and the improvement of human welfare, the need for high-performance materials continues to increase. At the beginning of the discovery of metal manufacturing technology, all metal-based products became a favorite to be used and developed in the industrial sector and the community. However, its use is limited to certain applications and has a fairly high economical price, resulting in the current use of metal being replaced by other products, one of which is composites. Biocomposite products are growing in line with the world's need for materials that are environmentally friendly and can be categorized as sustainable materials [1]. The criteria for environmentally friendly materials include a short process to be naturally degraded, can be reused into other products through environmentally friendly and economical processes, and reduce the composition/compounds that are not easily biodegradable and then replace them with materials that are easily degraded by nature [2].

Composite materials were initially introduced by using the characteristics of synthetic fibers combined with polymeric materials as a matrix. The purpose is to obtain the optimum mechanical strength of the material [3][4][5]. But in fact, synthetic fibers have a harmful impact on the environment due to waste from synthetic fibers that cannot be recycled. Synthetic fibers are commonly used in the form of fiberglass fibers with fiber characteristics that are difficult to degrade naturally and produce monoxide gas (CO) and dust that are harmful to health if the recycling process is carried out [6]. These factors that underlie the use of synthetic fiber composite materials are slowly being abandoned and switching to applications made from composite materials using natural fibers. Although not completely shifted, the use of natural fiber reinforcement to replace synthetic fibers is a wise step in saving the environment from waste created and limited natural resources that cannot be renewed. One type of natural fiber that can be used as a constituent of composite materials is corn husk [7].

Indonesian people are generally using the corn husk as a traditional food wrapper, as animal feed, and some handicrafts so that the use of corn husk as a product that has economical value is still considered less than optimal. Corn husk is a type of lignocellulosic natural fiber that has the potential to be developed into a composite material. The content of corn husk waste consists of 36.81% cellulose, 6.04% ash, 15.7% lignin, and 27.01% hemicellulose [8]. Cellulose is a natural fiber that has several advantages, namely being able to reduce sound/noise, temperature insulation, low density and high mechanical ability so that it can meet industrial needs.

The mechanical strength of the composite is influenced by several factors, one of which is the fiber volume. The tensile strength is influenced by the fiber volume fraction, the higher the fiber volume fraction, the higher the strength [9]. However, if voids or matrix-rich areas are found in a composite material, it can have

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an impact on decreasing the strength of the material even though the fiber volume fraction is high. This is because the area that is found to have voids or rich in matrix does not have reinforcement in that area[10].

This study aims to determine the effect of volume fraction of corn husk fiber as reinforcement in epoxy matrix composites on tensile strength and fracture patterns that occur in composite specimens. The parameters used are fiber volume fractions of 20%, 30%, 40%, and 50% with a fiber length of 165 mm. Composite specimens were made using the Vacuum Assisted Resin Injection (VARI) method with the purpose of minimizing the risk of voids and porosity in the material.

2 Research Method

2.1 Specimen Preparation

Corn husks was first soaked in water for 10 days. Furthermore, the corn husk was combed and cut according to a predetermined size of 160 cm. The fiber that has been cut was then dried in an electric oven with the aim of removing the moisture content of the fiber.

2.2 Alkalization Process

The fiber cleaning process (alkalization) was performed by soaking the fibers from the drying process in a 5% NaOH solution for 2 hours. Alkalization process was carried out at room temperature. The fiber resulting from the subsequent alkalization process was rinsed using running water to clean the fiber from the NaOH solution. The washed fibers were then cleaned using a tissue and sun dried.

2.3 Composite Manufacturing Process

The corn husk reinforced epoxy composites were made using the vacuum assisted resin infusion (VARI) method as shown in Figure 1 and the dimensions of the specimen as shown in Figure 2 with reference to the ASTM D638-03 standard [11][12].

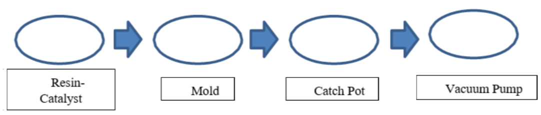

Fig. 1. Composite manufacturing with vacuum assisted resin infusion

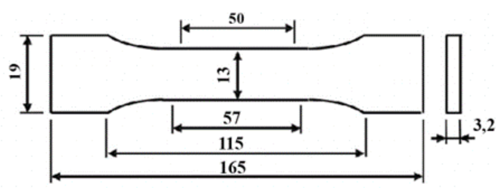

Fig. 2. Tensile test specimen

Before the fiber is placed in the vacuum infusion mold, the mold was first coated with wax to facilitate the release of the fiber later and was sealed at the end of the moldto avoid leakage. Furthermore, corn husk fiber with a length of 160 cm was placed on the mold with a layer of mesh netting and bagging film. Epoxy resin and hardener witha ratio of 2:1 were mixed in a resin pot and channeled into the specimen mold using the vacuum principle. The resin from the mold would come out into the catchpot and be left for 1 hour for the curing process. After the curing process was complete, the specimen was released from the mold and a tensile test was carried out.

2.4 Tensil Testing

Tensile testing was conducted to determine the mechanical characteristics of the composite specimen resulting from the vacuum assisted resin infusion process. The tensile test equipment used universal tensile testing machine with the spesification Tarno Test Grocki UPH model of 100 kN and has a capacity of 100 kN.

2.5 Composite Manufacturing Process

Macro and micro photo testing was used to analyze the fracture pattern of the tensile test specimens. Microstructure testing aims to be able to see how many voids and the presence or absence of a fiber pull out/debonding mechanism contained in the specimen. The results of the microstructure were then analyzed and discussed regarding its relationship to tensile strength.

3 Result and Discussion

3.1 Effect of Fiber Volume Fraction on Tensile Strength

The results of tensile tests carried out on corn husk fiber composite specimens with epoxy matrix with variations in fiber volume fraction of 20%, 30%, 40%, and 50% are shown in Figure 3 below

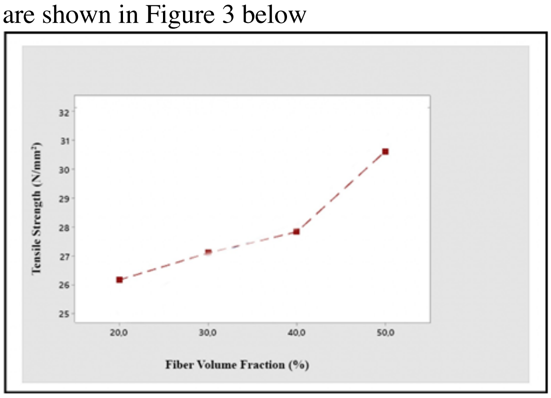

Fig. 3. Graph of the relationship between volume fraction and tensile strength

Figure 3. describes the average value of the tensile stress interaction between the volume fraction and fiber length. The relationship of the tensile stress value is

directly proportional to the increase in the fiber volume fraction, so the increase in fiber volume the tensile stress value increases. The fiber length of 165 mm at the fractions of 20%, 30%, 40%, 50% got the tensile stress values of 26.16 N/mm2, 27.09 N/mm2, 27.82 N/mm2, and 30.61 N/mm2. The highest tensile stress was obtained by the 50% volume fraction with a tensile stress value of 30.61 N/mm2 and the lowest tensile stress was obtained by the 20% volume fraction of 26.16 N/mm2. This increase is in accordance with the rule of mixture of composites that the composite strength increases with increasing fiber volume fraction. The force received by the matrix will be distributed evenly on the reinforcing fiber, so the greater the volume fraction of the fiber, the greater the force distributed on the fiber [13].

3.2 The results of the macro and micro structure test of the tensile test specimen

The fractures in the tensile test specimens were tested by macro and micro photos to determine the characteristics of the tensile test results. A macro photo of the fracture of a tensile test specimen with a fiber length of 165 mm is shown in Figure 4.

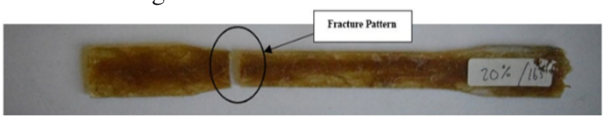

Fig. 4. Macrostructure of tensile test specimen fracture with a fiber length of 165 mm using of 20% volume fraction

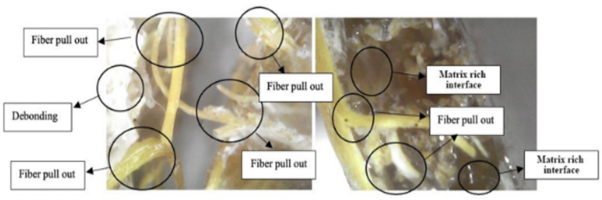

Fig. 5. Microstructure of tensile test specimen fracture with a fiber length of 165 mm using of 20% volume fraction

Figure 4. describes the shape of the fracture pattern that occurs, in this pattern it forms a perpendicular pattern which can be concluded to have a brittle material. Then Figure 5 is a microstructure in the fracture area of the specimen which shows the presence of several defect phenomena in the form of matrix rich interface defects, debonding and the fiber pull out. The matrix rich interface shows the occurrence of uneven fiber distribution, while fiber pull out and debonding occur due to the inability of the matrix to bind the fibers [14][15]. The fracture pattern and the microstructure of 50% volume fraction treatment are shown in Figure 6 and Figure 7.

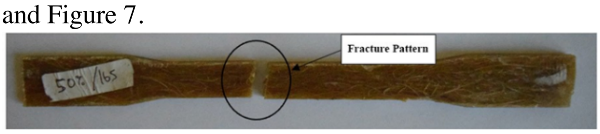

Fig. 6. Macrostructure of tensile test specimen fracture with a fiber length of 165 mm using of 50% volume fraction

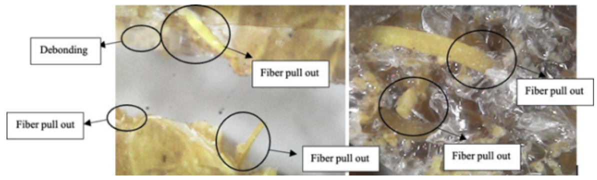

Fig. 7. Microstructure of tensile test specimen fracture with a fiber length of 165 mm using of 50% volume fraction

Figure 6. describes the shape of the fracture pattern that occurs in the specimen. In this pattern shows the wave pattern which can be concluded to have a ductile material. Figure 7. describes the fracture shape of the tensile test specimen with a fiber length of 165 mm with a volume fraction of 50%. The photo also explains the composite defects in the form of fiber pull out and debonding which can be concluded that the matrix is unable to bind the fibers but in this specimen there is no matrix rich defect where the fibers are evenly distributed.

4 Conclusion

Based on the results of the research above, it can be concluded several things as follows:

1. The addition of corn husk fiber volume fraction to the epoxy matrix composite can increase the tensile stress value. As the volume fraction value increases, the tensile strength value also increases. Tensile strength values for fiber length of 165 mm with variations in fiber volume fraction 20%, 30%, 40%, and 50% get the tensile stress values of 26.16 N/mm2, 27.09 N/mm2, 27.82 N/mm2, and 30.61 N/mm2.
2. Composites with a volume fraction of 20% contain a lot of matrix rich defects, fiber pull out and debonding, resulting in decreased tensile strength. Rich matrix which indicates the distribution of fibers in the composite is not evenly distributed so that there is still a lot of empty space without matrix and fiber bonds. In the 50% volume fraction there are fewer defects in fiber pull out and debonding, which results in higher tensile strength. It can be concluded that the volume fraction can affect the tensile strength of the composite

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