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Analysis of The Effect of Volume Fraction Variation on Tensile And Bending Strength of Composite Fiber Combination of Pineapple Leaves And Fiberglass With Polyester Resin Matrix By Compression Molding Method

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***Abstrak**, Pineapple leaf fiber is a waste that is widely found on the island of Sumatra and its potential utilization has not been maximized. Pineapple leaf fiber has potential as a constituent of natural fiber composites. This study aims to determine the effect of volume fraction variation on tensile and bending strength reinforced with pineapple leaf fiber and fiberglass. The composite manufacturing process uses the compression molding method for 24 hours with a pressure of 50 bar and is given a variation of 70% polyester resin, 25% fiberglass, 20%, 15%, 10%, 5%, and 25%, 20%, 15%, 10%, 5% pineapple leaf fiber. After completion of the composite manufacture, density and porosity testing was carried out with ASTM C271 standards, tensile testing was carried out using D3930 standards and bending testing using D790 standards. The lowest density test results and the highest porosity in composites with 70% resin variation, 25% fiberglass, 5% pineapple leaf fiber with a value of 0.87 gr/cm3 - 7.80% and the highest density value and the lowest porosity with 70% resin variation, 5% fiberglass, 25% pineapple leaf fiber with a value of 1.81 gr/cm3 - 1.53%. The highest tensile strength test results in the variation of 5% fiberglass volume fraction 25% pineapple leaf fiber of 237.76 MPa, and the lowest value in the variation of 25% fiberglass volume fraction 5% pineapple leaf fiber of 98.37 MPa. And the highest bending test was obtained in the variation of the volume fraction of 5% fiberglass 25% pineapple leaf fiber at 332.14 MPa, and the lowest value was obtained in the variation of 25% fiberglass 5% pineapple leaf fiber at 194.95 MPa.*

***Kata kunci** : Fiberglass, pineapple leaf fiber, density, porosity, tensile test, bending test.*

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1. Introduction

The development of an increasingly advanced era has led to the development of equipment used by society, such as means of production, means of transportation, communication media, information media, entertainment, and others [1][2]. Composite is a material formed from a combination of two or more components through an inhomogeneous mixing process, where the mechanical properties of each component are different [3][4]. In general, the types of composites can be divided into three types, namely fibrous composites, laminated composites, particulate composites [5][6]. The matrix serves as a support for the fibers and protects them from mechanical damage, while the fibers increase the strength and hardness of the material [7].

Natural fiber composites have excellent development prospects in Indonesia. Some of the reasons include the fact that Indonesia can grow most of the plants that produce natural fibers, such as hemp fiber (kenaf), palm fiber, enau, water hyacinth, pandanus, coconut husk, and pineapple leaves. This can increase the potential impact of local renewable natural resources. [8].

Pineapple leaf fiber is a type of vegetable natural fiber derived from pineapple leaves. Pineapple leaves are shaped like swords, have pointed tips, and are greenish black in color. The edges of the leaves have sharp spines between the layers there are many bonds or bundles of fibers that are bound to one another by a kind of adhesive substance (gummy substances) contained in the leaves [7]. In addition to pineapple leaf fiber, fiberglass can also be used as an alternative material for making composites. Fiberglass has different properties. The production cost is low, the production process is very simple, giving glass fiber a superior

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ratio (comparison) of price and performance. Fiberglass, a type of fiber composite material, is widely used in aircraft secondary structures such as fairings, radomes, and wing tips, as well as helicopter propellers. Glass fiber is composed of silica, alumina, lime, magnesia, etc [9].

The main advantage of using composite materials is the combination of high strength and stiffness properties and low specific gravity. By selecting appropriate fiber and matrix materials, composites can be made with new material properties suitable for specific purposes. Currently, the use of composite materials in engineering is increasing along with the increasing knowledge of the properties of these materials, and the manufacturing costs required are relatively the same and tend to be lower than conventional materials [10].

Hybrid composites are composites that use 2 or more fibers as reinforcement. From the journal Fajar Paundra, et al (2022), hybrid composites reinforced with banana frond fiber and polyester-matric pineapple leaf fiber show the highest tensile strength value is in the variation of volume fraction 20: 10 (banana frond fiber: pineapple leaf fiber) of 26.55 MPa.

Although research on pineapple leaf reinforced composite materials has been conducted, no research has been conducted on the combination of pineapple leaf reinforced composite materials and fiberglass with compression molding method. The purpose of this research is to analyze the effect of variation in volume fraction of pineapple leaf fiber composite and polyester matrix glass fiber on tensile strength and bending strength using compression molding method. The material used for making composites is polyester resin with pineapple leaf fiber and glass fiber as reinforcement.

2. Methodology

The materials used in this research are pineapple leaf fiber and fiberglass as reinforcement, while the matrix uses Unsaturated Polyester Resin Yukalac C-108B. The fiberglass is cut according to the mold while the pineapple leaf fiber is cut along 5 cm. then the pineapple leaf fiber is soaked using 5% NaOH for 2 hours, with the aim of removing dirt on the pineapple leaf fiber.

Composite manufacturing is done by compression molding method with fiber composite form. The manufacturing process begins with applying wax to the mold so that the composite does not stick when removed from the mold. After that, the resin in liquid form is mixed with pineapple leaf fiber and fiberglass which have been combined according to their respective compositions, after which they are inserted into the mold. The composite was pressed at 5 bar for 24 hours. This aims to remove the air trapped in the composite and the composite dries perfectly.

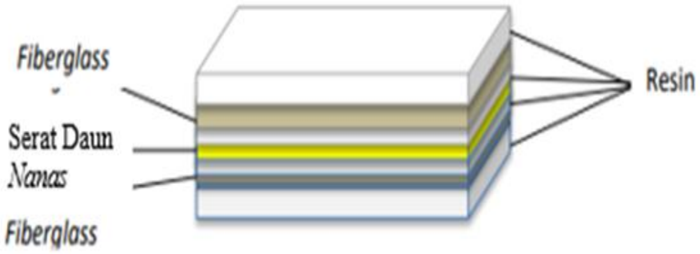

Figure 1. Illustration of fiber layout

The volume fraction used in the composite is 70% matrix and 30 pineapple leaf fiber and fiberglass. These fibers were varied in such a way as to match the volume fraction. Table 1 shows the variation of the volume fraction used.

Table 1. Comparison of Composites

Resin (%)	Fiberglass (%)	Pineapple Fiber (%)
70	25	5
70	20	10
70	15	15

70	10	20
70	5	25

The resulting composite material of pineapple leaf fiber and fiberglass will be subjected to tensile and bending testing. Tensile testing refers to ASTM D3039 and bending testing refers to ASTM D790. Then the results of the fracture are observed to determine the characteristics of the composite fracture.

3. Result and Discussion

3.1 Density

Density testing is an important measurement tool in the scope of composites, because it greatly affects the properties of composite materials [26]. The following is a density graph obtained from the results of testing fiberglass composites and polyester-matrixed pineapple leaf fibers with varying volume fractions. Figure 2 is the result of the composite density test.

The largest density value belongs to the variation of 5% fiberglass volume fraction: 25% pineapple leaf fiber has a value of 1.81 gr/cm3, while the lowest porosity value belongs to the variation of 25% fiberglass volume fraction: 5% pineapple leaf fiber has a value of 0.87gr/cm3. And from Figure 2, it can be interpreted that as the volume fraction variation of pineapple leaf fiber increases, the density value will increase. This is in accordance with the research of Mujiyono, et al [27] yang menyatakan bahwa nilai densitas serat daun nanas lebih tinggi dari fiberglass. The density value will affect the strength of the composite, if the density value is higher, the composite strength will be higher and vice versa [28].

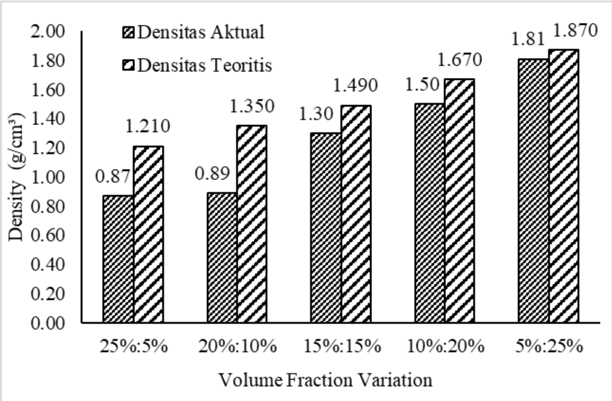

Figure 2. Density Graph

3.2 Porosity

Porosity occurs due to defects that exist in the composite specimen during the manufacturing process. Figure 3 is a composite porosity graph.

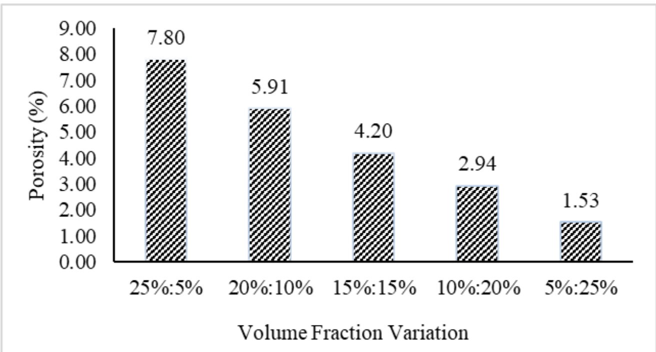

Figure 3. Porosity Graph

The largest porosity value is owned in the variation of the volume fraction of 25% fiberglass: 5% pineapple leaf fiber which has a porosity value of 7.80%. The high porosity value is caused by many defects in the specimen, resulting in high porosity which results in a decrease in the strength of the composite specimen. While the lowest porosity value is owned in the variation of the volume fraction of 5% fiberglass: 25% pineapple leaf fiber has a porosity value of 1.53%. The low porosity value is due to the material not experiencing material failures such as defects in the specimen, this has an impact on the high strength value of the specimen [24].

3.3 Tensile Test

The purpose of conducting tensile testing is to find the effect of variations in volume fractions referring to and the types of mechanics in composites that refer to the ASTM D3039 standard. Figure 4 is the maximum tensile strength of the composite.

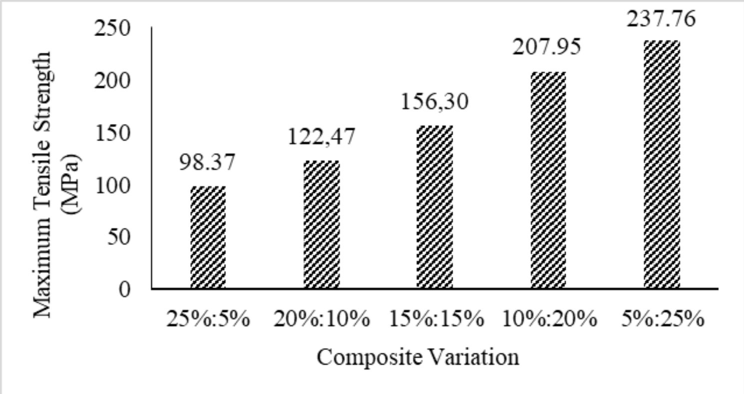

Figure 4. Tensile Strength Graph

The value of the maximum tensile strength where the highest tensile strength value is obtained in the composite specimen with a volume fraction variation of 5% fiberglass: 25% pineapple leaf fiber composite which is getting a value of 237.76 MPa, while the smallest tensile strength value is obtained in the volume fraction variation of 25% fiberglass: 5% pineapple leaf fiber composite which has a value of 98.37 MPa. The more the volume fraction of pineapple leaf fiber increases, the greater the tensile strength of the composite. This is in accordance with the research of L. Yanuari (2022) which states that the tensile strength value of pineapple leaf fiber is higher than the tensile strength value of fiberglass [27]. Figure 5 is the elastic modulus of the composite tensile test.

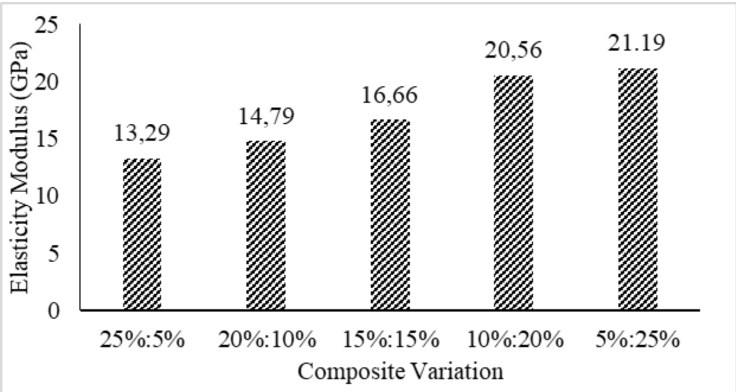

Figure 5. Tensile Test Modulus of Elasticity

The elastic modulus value which has the highest value is obtained in 5% fiberglass: 25% pineapple leaf fiber which has a value of 21.19 GPa, while the lowest value is obtained in 25% fiberglass: 5% pineapple leaf fiber which gets a value of 13.29 GPa. The elastic modulus value is directly proportional to the tensile strength value.

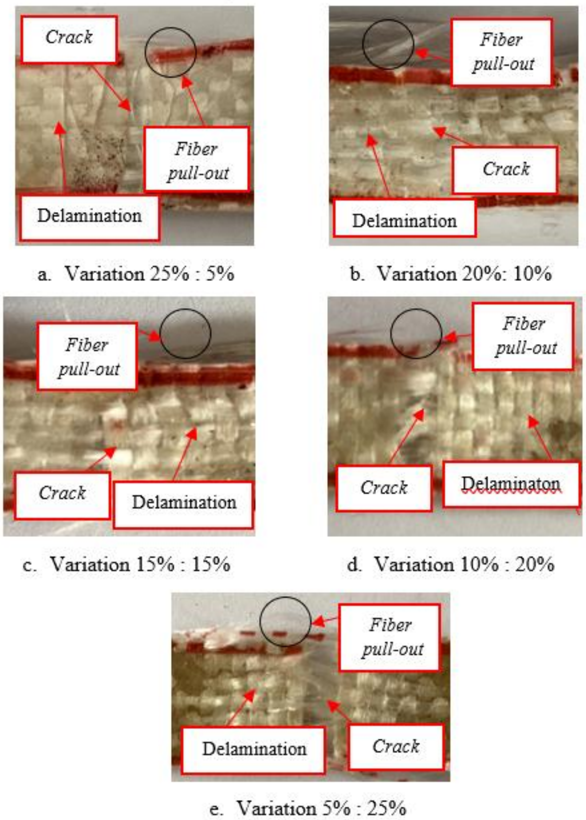

Figure 6. Tensile Test Fracture Results

Figure 6 shows the fracture results of the composite tensile test. The fracture results show that crack deflection, fiber pull-out and delamination occur. The cause of the crack or crack is the result of the force load received by the composite specimen resulting in crack lines or cracks until a fracture occurs. The cause of delamination is the clumping of fibers in the composite material so that the load is not evenly distributed to the matrix. Fiber pull-out occurs when transferring the load by the fiber to the matrix is not perfect. When the load that has been given can still be accepted by the fiber but the matrix is no longer able to accept so that the matrix is broken but the fiber can still hold it so that the fiber is pulled out and fiber pull-out appears [29]. Variation of 25% fiberglass: 5% pineapple leaf fiber and 20% fiberglass: 10% pineapple leaf fiber type of fracture is a fiber fracture, failure with an indication of brush fracture in this specimen occurs due to fiber failure when continuing the load given by the matrix [30]. Variation 15% fiberglass: 15% pineapple leaf fiber is a fracture starting from the matrix and fiber in the outermost layer of the crack, but the fiber is still able to connect to the other layers, where the remaining one layer is usually the lowest in the form of a matrix and glass fiber still not broken and makes the specimen still fused. Variation 5% fiberglass: 25% pineapple leaf fiber type of fracture is a brittle fracture because at the time of testing the crack occurs quickly without previous plastic deformation and in a fast time, the shape of the fracture is perpendicular.

3.4 Bending Test

The maximum three-point bending strength is generated from the data obtained from testing specimens with a combination of pineapple fiber and fiberglass. Figure 7 shows a graph of the maximum bending strength. The bending test results above can be seen that the highest bending strength value is in the variation of 5% fiberglass volume fraction: 25% pineapple leaf fiber which has a value of 332.14 MPa, while the lowest bending strength is in the variation of 25% fiberglass volume fraction: 5% pineapple leaf fiber which has a value of 194.95 MPa.

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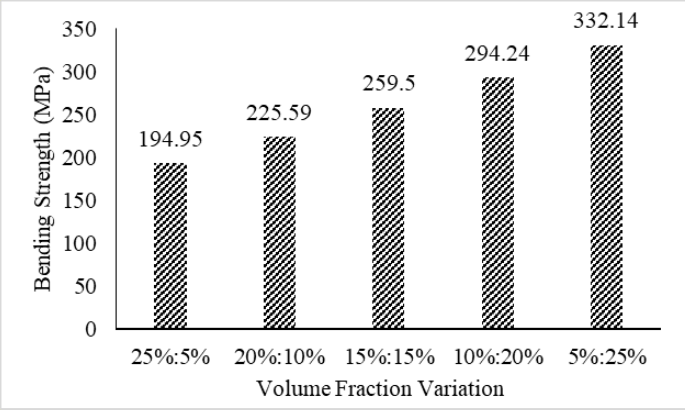


Figure 7. Bending Strength Graph

From the bending test value, it can be concluded that the greater the volume fraction of pineapple leaf fiber, the higher the bending test strength value on the composite material of fiberglass and pineapple leaf fiber. This is due to the strength of pineapple leaf fiber which has a fairly high flexibility and the strength of the fiberglass bond is quite good so that the force received can be well distributed between the matrix and the fiber in the composite [31].

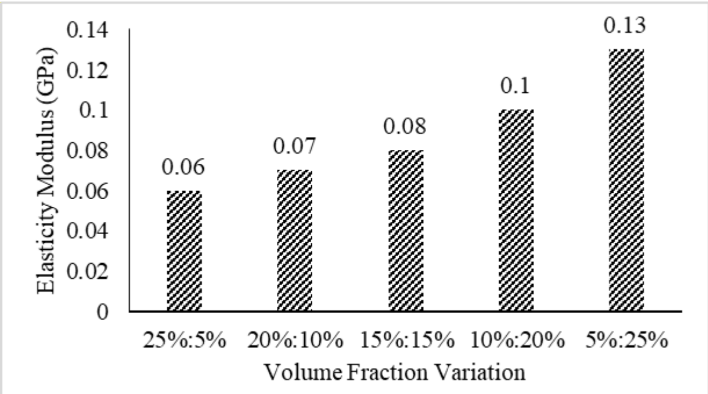
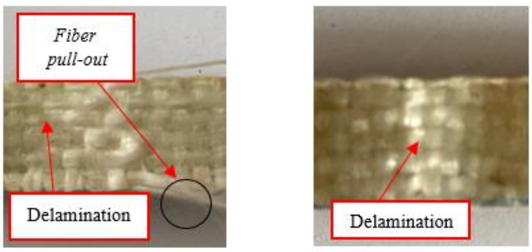


Figure 8. Bending Test Modulus of Elasticity

The elastic modulus value that gets the largest value is the variation of 25% fiberglass volume fraction: 5% pineapple leaf fiber which has a value of 0.13 GPa while the smallest value is the variation of 25% fiberglass volume fraction: 5% pineapple leaf fiber which has a value of 0.06 GPa. The elastic modulus value is directly proportional to the bending strength value. This elastic modulus is the result of the comparison between the bending strength value and the strain value of the composite. Table 2 shows the results of the composite bending test. Figure 8 shows the elastic modulus in the composite bending test.

Shows the results of fracture photos that have been carried out bending tests that are ductile so that springback occurs. Springback is the return force generated during bending testing due to the effect of elasticity on hybrid composite specimens [24]. Table 2 shows the bending test fracture results.



a. Variation 25% : 5%   b. Variation 20% : 10%

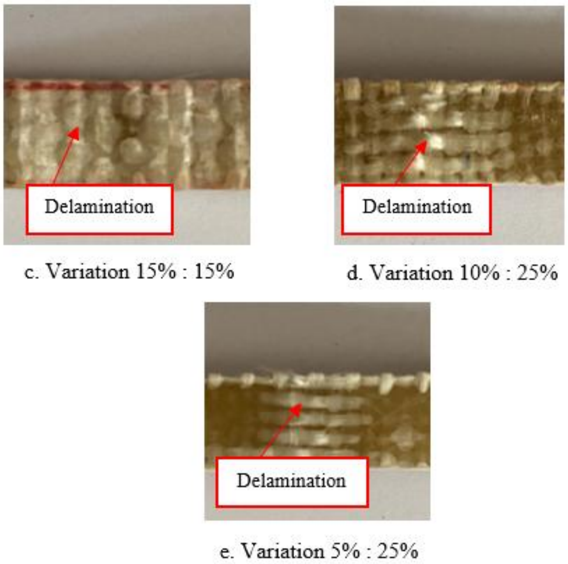


Figure 9. Bending Test Fracture Results

The cause of delamination is fiber clumping in the composite material so that the load is not evenly distributed to the matrix. Fiber pull-out occurs when the load transfer by the fiber to the matrix is not perfect [29]. Variation of 25% fiberglass: 5% pineapple leaf fiber and 20% fiberglass: 10% pineapple leaf fiber experienced fiber pull-out and delamination fractures, this is because a lot of fiberglass is unable to withstand the load during testing, while the picture 15% fiberglass: 15% pineapple leaf fiber, 10% fiberglass: 20% pineapple leaf fiber and 5% fiberglass: 25% pineapple leaf fiber only experienced delamination fractures, this is because many pineapple leaf fibers can withstand the load that has been given at the time of testing, this happens because pineapple leaf fiber is more flexible than fiberglass.

4. Conclusion

The highest tensile strength result value is found in the variation of 5% fiberglass volume fraction: 25% pineapple leaf fiber, namely 237.76 MPa, while the smallest value of tensile strength is found in the variation of 25% fiberglass volume fraction: 5% pineapple leaf fiber, namely 98.37 MPa. The more the volume fraction of pineapple leaf fiber increases, the greater the tensile strength of the composite. This is because the tensile strength value of pineapple leaf fiber is higher than the tensile strength value of fiberglass.

The highest bending strength value is obtained in the variation of 5% fiberglass volume fraction: 25% pineapple leaf fiber which is 304.97 MPa, while the lowest bending strength is found in the variation of 25% fiberglass volume fraction: 5% pineapple leaf fiber which has a value of 194.95 MPa. The greater the volume fraction of pineapple leaf fiber, the higher the bending test strength value of fiberglass and pineapple leaf fiber composite materials. This is due to the strength of pineapple leaf fiber which has a fairly high flexibility and the strength of the fiberglass bond is quite good.

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