# Effect of Sisal Fiber Direction Angle on Physical and Mechanical Properties of Composites

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Abstract: Research on the effect of sisal fiber angle on density, water absorption, porosity, flexural strength, impact strength, and tensile strength of sisal-epoxy resin composite fibers. Composites are made by hand lay out method in the composition of sisal fiber material: epoxy resin = 10 wt% : 90 wt% with the fiber angle orientation layout at: 0°, 30°, 45°, 60°, 90°. Composite properties obtained have an average density of 1.2 $g/cm^3$, water absorption increases linearly, and porosity of composites rises linearly to changes in angle increment which is greater and has flexural strength, impact strength, composite tensile strength linearly decreases to changes in the incremental angle. Optimal mechanical properties occur at the angle of fiber 0°, this is due to the long fiber direction, in the direction of the tensile force which is at 0°. The length of each fiber at 30°, 45°, 60°, 90°, will have lower mechanical properties, due to the shorter load distribution.

## 1 INTRODUCTION

Composite is a material that is formed from a combination of two or more materials that are macro and insoluble to one another (GuruRaja, 2013). One forming element is called an amplifier and one element is called a binding (GuruRaja, 2013). Reinforcing agents can be in the form of fibers, particles, or flakes (GuruRaja, 2013)(Hodzic, 2013).The role of the matrix in the composite material is to give shape to the composite part, protecting the reinforcement and perfection of the material, together with the reinforcement (Parandoush, 2017). Composite materials are used for cars, ships, airplanes, sporting goods and so on (GuruRaja, 2013).

The nature of composite materials is strongly influenced by the nature and distribution of the constituent elements, as well as the interactions between the two (Hodzic, 2013). Important parameters that influence the nature of the composite material are the shape, size, orientation and distribution of the amplifier (filler) as well as the characteristics of the matrix (Pickerig, 2015). The mechanical properties of composite materials depend on the nature of the constituent materials (Pickerig, 2015). The main role in fiber-reinforced composites is to move stress between the fiber, provide resistance to the environment, maintain the surface of the fiber, mechanical and chemical effects (Hodzic, 2013). The contribution of fiber is largely influential on the mechanical strength of composite materials (Pickerig, 2015).

The choice of natural fibers and matrix materials, fiber orientation, fiber arrangement is one of the significant ways to increase the strength of composites (Woo, 2006). Testing the angle of orientation of the fiber is very important so it takes a lot of effort to do research (GuruRaja, 2013) (Woo, 2006) (Marin, 2019). Therefore, researchers are interested in knowing the physical and mechanical properties of making sisal fiber composite boards with epoxy resin with orientation toward sisal fiber at 0°; 30°; 45°; 60°; 90° is expected to produce composites that are stronger, tougher, stronger and meet quality standards so that they can be utilized by industry (Naraganti, 2017) (Marin, 2019) (Kretsis, 1987).

Environmentally friendly composite materials based on natural fibers can be obtained around the environment (Pickerig, 2015). Natural fibers are now widely used because of their abundance and are so cheap that they are often used as reinforcing materials such as kenaf, abaca, rosella, straw, sisal and many natural fibers which are quite abundant in Indonesia and can be renewed (Hodzic, 2013). Epoxy resins have wide uses in the chemical, electrical, mechanical, and civil chemical industries as



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adhesives, coating paints, and printed objects (Baheshtizadeh, 2018) (Kretsis, 1987). Besides having high strength, epoxy resin also has good chemical resistance (Baheshtizadeh, 2018) (Kretsis, 1987). Sisal is the most widely used natural fiber, most of this economical and renewable material has not been fully utilized Naraganti,(Hodzic, 2013). At present the main use of sisal is limited to the fields of marine and agriculture (Naraganti, 2017). Sisal fiber applications include the manufacture of yarn, ropes, mats, fish nets (Naraganti, 2017).

# 2 MATERIALS

The material used is sisal fiber obtained from Surabaya sisal rope suppliers, epoxy resin and epoxy hardener obtained from the chemical store PT. Justus Kimiaraya. The tools used are digital balance sheet, hot press, 2 pieces of iron plate, sample molds, GOTECH Universal Testing Machine (UTM), GOTECH Impactor.

# 3 METHODS

The selection of sisal fiber, described to obtain the smallest strands used as reinforcement, is then prepared by epoxy resin and hardener in a ratio of 2: 1. Made fiber mass: epoxy resin mass = 10 wt%: 90 wt%, then calculate the fiber mass and epoxy resin mass. prepare the mold, then arrange the direction of the fibers at 0°, 30°, 45°, 60° and 90° on each composite board, glue together, mix the resin and hardener into the measuring cup, stir evenly, pour the resin and hardener mixture into the mold that has been glued to the fiber, evenly, closed the mold using a second iron plate coated with aluminum foil and waxed. Furthermore, the mold is placed on a hot press, pressurized 5 tons at a temperature of 90°C within 20 minutes. Then the sample is removed, conditioned 1 x 24 hours. Composite boards are cut to standard test sizes, and samples are made in the same way at an angle of 30°; 45°; 60°; 90°, then each sample is ready to be tested.

# 4 RESULTS AND DISCUSSION

## 4.1 Density Test

Testing the density of sisal-epoxy fiber composites is first weighed on the composite mass, then the sample volume is measured to be able to calculate the composite density. The results of the measurement of composite density with the orientation angle of the fiber 0°; 30°; 45°; 60°; 90° shown in the following figure 1.

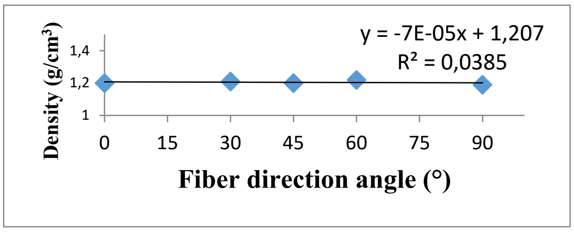


Figure 1: Density vs fiber direction angle.

From Figure 1 above it can be analyzed that the relationship between density and fiber direction angle is 0°; 30°; 45°; 60°; 90° tends to be linearly flat, this is due to the fact that the mass of the fiber remains for each change in direction angle of the fiber at 0°; 30°; 45°; 60°; 90°, so that it will produce a fixed composite density. The average density of sisal-epoxy fiber composites is 1.2 g/cm$^3$.

## 4.2 Absorption Water Test

Composite water uptake was carried out to determine the percentage of water absorbed by the composite soaked in water for 24 hours. Water absorption tests have been carried out on composites with each fiber angle orientation 0°; 30°; 45°; 60°; 90°. The results of the composite water absorption test are shown in Figure 2 below.

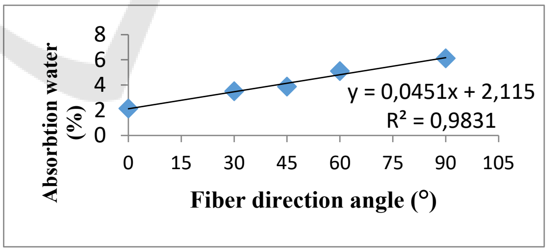


Figure 2: Absorption water vs fiber direction angle.

From Figure 2 above it can be analyzed that the relationship between composite water uptake and fiber direction angle at 0°; 30°; 45°; 60°; 90° tends to rise linearly, this is due to the arrangement of the laying direction of the fiber at 0°; 30°; 45°; 60°; 90° has a fixed mass, but when cutting a composite board sample results in the cut section of the incision having fibers not covered by epoxy resin getting bigger.

## 4.3 Porosity Test

Composite porosity test is performed to determine the ratio between pore volume to total volume of the composite. Porosity test has been carried out with the orientation of sisal fiber angle at 0°; 30°; 45°; 60°; 90°, the results of the composite porosity test with the orientation angle of the sisal-epoxy fiber are shown in Figure 3 below.

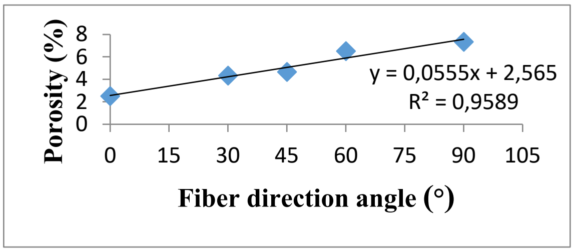


Figure 3: Porosity vs fiber direction angle.

From Figure 3 above it can be analyzed that the relationship of porosity of the composite with the fiber direction angle at 0°; 30°; 45°; 60°; 90°, tends to increase linearly, this is due to the increase in the direction angle of the composite fiber at the same mass and when cutting the test sample will cause the porosity of the composite to rise. At the incision of the sample trapped air between sisal fibers, can not be pressed out and form air bubbles or voids so susceptible to porous.

## 4.4 Flexural Strength Test

The flexural strength test uses the GOTECH Universal Testing Machine type Al-7000M, to determine the resistance of the composite to loading at three bending points and also to determine the elasticity of the composite. The results of the composite flexural strength test with the fiber direction angle at 0°; 30°; 45°; 60°; 90°, shown in figure 4 below.

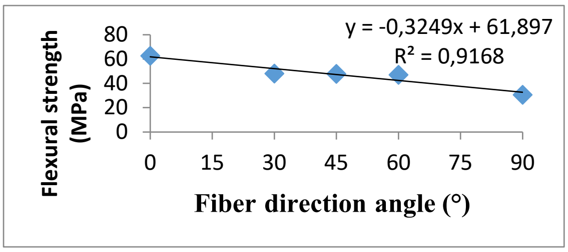


Figure 4: Flexural strength vs fiber direction angle.

From Figure 4 above it can be analyzed that the relationship between the flexural strength of the composite with the fiber direction angle 0°; 30°; 45°; 60°; 90° tends to decrease linearly. This is because the load from the matrix to the fiber is smaller and the interfacial bond is even stronger, because the length of the fiber at 0° gives higher strength than the shorter fiber length. Composite flexural strength at the angle of fiber 0o has the greatest flexural strength of 62.72 MPa, compared to other flexural strengths due to the long pieces of fiber arranged on the 0° composite being longer than the fibers arranged at an angle of 30°, 45°, 60°, and 90°.

## 4.5 Impact Strength Test

The test samples used were rectangular in accordance with ASTM D256. Impact testing is done with the GOTECH Impactor tool. Strong composite impact test results with fiber angles at 0°; 30°; 45°; 60°; 90°, shown in figure 5 below.

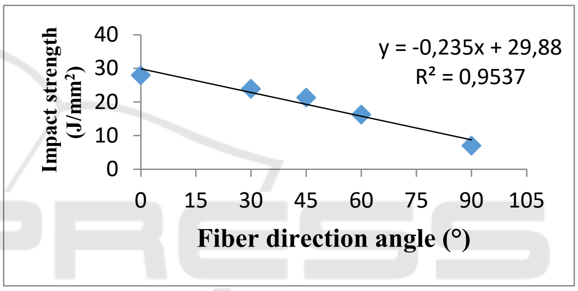


Figure 5: Impact strength vs fiber direction angle.

From Figure 5 above we can analyze the impact of the strong impact on the fiber direction angle at 0°; 30°; 45°; 60°; 90°, tends to be linearly decreased, this is because the shorter fiber length will have a bond between and the matrix is much lower than the fiber length at 0°. The maximum impact strength is 27.97 J/mm$^2$ and there is a decrease in impact strength at each decrease in fiber direction angle.

## 4.6 Tensile Strength Test

The test sample used is rectangular in shape, the size is adjusted to ASTM D 638-01 standard. Flexural strength test is performed using the GOTECH Universal Testing Machine type Al-7000M. The results of the composite tensile strength test with a fiber angle of 0°; 30°; 45°; 60°; 90°, presented in Figure 6 below.

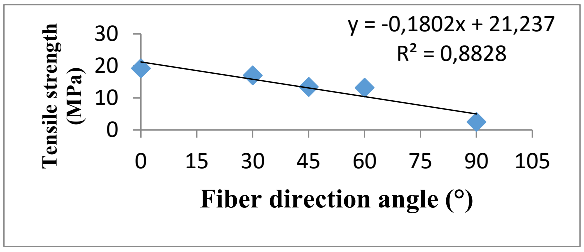


Figure 6: Tensile strength vs fiber direction angle.

From Figure 6 above it can be analyzed that the relationship of flexural strength to the angle of orientation of the fiber decreases linearly, this is due to the change in the angle of direction of the fiber at 0°; 30°; 45°; 60°; 90° gives a lower tensile strength, due to the load received by the fiber at each lower angle, because the distribution of load to the fiber will decrease lower at a greater fiber angle. The greatest tensile strength of composites occurs at a direction angle of 0o by 19.28 MPa, and a decrease occurs due to the length of the fibers arranged at 0° longer than the length of fibers arranged at an angle of 30°; 45°; 60°; 90°, so the distribution of the load on the composite decreases.

## 5 CONCLUSIONS

From the results of the study the influence of the direction angle of sisal fiber with composite epoxy resin can be concluded that:
Sisal fiber composites - epoxy resin with fiber mass ratio: epoxy resin mass is 10 wt%: 90 wt% has an average density of 1.2 g/cm$^3$, water uptake rises linearly and porosity also rises linearly for each change in direction angle fiber at 0°; 30°; 45°; 60°; 90°. The flexural strength of the composite has decreased linearly, the impact strength of the composite also has decreased linearly and the tensile strength has also decreased linearly at each change in the angle of direction of the fiber at 0°; 30°; 45°; 60°; 90°. Composite properties at sisal fiber direction angle with epoxy at 0° shrinkage, 30° angle, 45° angle and 60° angle, can be used as a car bumper material, composite flexural strength greater 32 MPa.

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