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ANALYSIS OF NUMBER OF LAYERS AND VOLUME FRACTION OF FIBER AGAINST SHOCK LOAD AND COMPOSITE COMPRESSIVE STRENGTH WIND TURBINE PROPELLER

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Abstract. The manufacture of wind turbine blades has a very high risk of failure, especially in the manufacturing section or in this case the material structure. If the structure of the propeller material is not able to withstand the very high pressure and air flow, it will result in the failure of the material structure when it is in use. For this reason, the purpose of this study was to determine the composition of composite materials that have high strength and toughness properties and are suitable for wind turbine propellers. The method used in this research is experimental. The independent variables include the number of layers and the volume fraction of straw fiber. The dependent variables are shock load and compressive strength. Each compression test specimen is made with a gauge length of 100mm, a width of 25mm, and a thickness of 2.5mm. While the impact test specimens are made equal to l25mm long, l2mm wide, l2mm high, and 2mm notch. The results showed that the bending strength of the straw fiber composite with 6 layers had an increasing trend as the number of layers increased. The highest bending strength with the number of piles of 6 layers and the lowest strength with the number of piles of 2 layers. In addition, the volume fraction is very influential on the bending stress of the straw composite matrix. It can be seen that the matrix with a volume fraction of 50% has the greatest bending stress in each number of layers, both 2, 4 and 6. For the impact test, it is found that the optimal number of layers occurs in the number of 2 layers with a volume fraction of 33%. The shock load tends to decrease. Meanwhile, based on the volume fraction, the larger the volume fraction, the smaller the shock load that can be received by the straw fiber composite material.

Keywords : composite, number of layers, volume fraction, shock load, compressive strength.

1. INTRODUCTION

The increase in the need for electrical energy occurs due to high population growth, but this is not balanced with the increase in the supply of electricity, while the needs of the community continue to increase. Indonesian people depend on PLN's supply, not only for lighting needs but also to support economic activities. Power plants owned by PLN generally use non-renewable energy, to meet the ever-increasing demand for electrical energy, power plants are needed by utilizing existing resources. Geographically, Indonesia has the potential to develop renewable alternative energy power generation. One of them is wind energy that blows relatively stable throughout the year with an average speed of 5 m/second [1].

To produce wind turbine blades that have reliability in producing optimal rotation, the main aspect that needs to be considered is the structure of the turbine blades themselves. For this reason, wind turbine propellers need to be composed of material structures or materials that have high strength or toughness [2], [3]. So that the composite material was chosen. The materials or materials commonly used in making wind turbine propellers are polyfoam, styrofoam, EPO foam, and balsa wood which have many advantages and disadvantages [4]. Because the addition of fiber to the foam will increase its mechanical properties, the weakness of this material is that it is easy to flutter [5].

The flutter phenomenon is a phenomenon of dynamic instability of a system caused by the interaction between the elements of inertia, damping, and flexibility of the structure, as well as aerodynamic loads acting on the structure. In other words, flutter is caused by a very high velocity air flow with an energy greater than the propeller structure's ability to dampen the energy (vibration), therefore vibration or flutter is one of the factors that need to be considered. Therefore, the purpose of this study was to analyze the number of layers and volume fraction of straw fiber against shock loads and compressive strength of wind turbine propeller composites.

Fiber is a type of material in the form of pieces - pieces form a network that is elongated and intact, fiber can be divided into two types, namely synthetic fibers and natural fibers. Synthetic fibers are fibers made by humans not from nature. As for natural fibers, namely fibers that come from nature. Natural fiber or you can say this natural fiber is usually obtained from plant fibers such as bamboo trees, coconut trees, banana trees and other plants that have fiber in their stems and leaves. Natural fibers derived from animals, including silk, ilama and wool [6], [7]. In composites, fiber is the main material that has a use as a reinforcement of the composite, with its use as a reinforcement in fiber composites which greatly affects the strength resulting from the composite material. Fiber composites in the industrial world began to be developed instead of using particles. In the development of processing technology, the use of fiber is now increasingly superior to the matrix material used. The fibers used can be glass fibers, carbon fibers, aramid fibers (poly aramide), natural fibers and so on. Fiber composite materials are composed of fibers bound by an interconnected matrix. The use of fiber composite materials is very efficient in receiving loads and forces that are in the direction of the fiber, on the other hand it is very weak when loaded in the direction perpendicular to the fiber [8]. Research that combines matrix and fiber must consider several factors. Long fibers can carry loads and stresses from the point of tension to other fibers. In an ideal continuous fiber structure, the fibers will be stress free or have the same stress. During fabrication, some fibers will receive high stresses and others may not be subjected to stress so the above state cannot be achieved. While short fiber composites, with the correct orientation, will produce greater strength when compared to continuous fiber. Short fiber composites can be produced with low surface defects so that their strength can reach their theoretical strength.

The shape of the fiber used for the manufacture of composites does not really affect, what affects is the fiber diameter. In general, the smaller the fiber diameter, the higher the composite strength. In addition to the shape, the fiber content also affects [9].

The matrix in the composite serves as a binding material for the fibers into a structural unit, protects against external damage, transmits or transfers external loads in the shear plane between the fiber and the matrix, so that the matrix and fiber are interconnected. The manufacture of fiber composites requires a strong surface bond between the fibers and the matrix. In addition, the matrix must also have a chemical match so that unwanted reactions do not occur on the contact surface between the two. To choose a matrix, its properties must be considered, such as resistance to heat, resistance to bad weather and resistance to shock, which are usually considered in the selection of matrix materials. There are two kinds of polymer materials used as matrix materials in composites, namely thermoplastic and thermoset.

The amount of fiber content in the composite is a matter of particular concern in fiber-reinforced composites. To obtain high-strength composites, the distribution of fibers with the matrix must be evenly distributed during the mixing process to reduce the occurrence of voids. To calculate the volume fraction, the parameters that must be known are resin density, fiber density, composite weight and fiber weight. If during the manufacture of the composite fiber and matrix mass, as well as fiber and matrix density are known, then the volume fraction and fiber mass fraction can be calculated by the equation [10],[11] .

The use of fiber in the composite aims to improve the properties and structure of the matrix that it does not have, it is also expected to be able to become a matrix reinforcement material in the composite to withstand the forces that occur. Fiber has been known since ancient times because of its strong structure, especially its tensile strength.

In addition, fiber is also the most important element, because it is the fiber that will determine the mechanical properties of the composite such as stiffness, ductility, strength and so on. Fibers are thin and long, and have sufficient characteristics in their internal structure. There are two types of fibers based on their constituent elements, the first is natural fibers, namely fibers from animals, plants and minerals, for example cotton, wool, silk, hemp and other natural fibers. The two synthetic fibers (synthetic fibers) are man-made fibers such as nylon, rayon, polyester acetates and others. In this study using natural fiber, namely straw fiber. Straw is the part of the growing stem that has been harvested with the grains of fruit (rice) together or not with the stalk reduced by the roots and the remaining part of the stem. At this time the use of straw is less efficient, usually only for livestock needs and for gardening purposes as fertilizer, even in the end it is only burned to cause pollution. So there is a lot of straw waste from rice farming. Now, with further research, it turns out that straw can also be used as a filler material in composite materials. With this abundant availability, straw can be used as a cheap and environmentally friendly composite fiber.

According [12], [13] the matrix is the phase in the composite which has the largest (dominant) portion or volume fraction. The matrix has the function of transferring tension to the fiber, forming a coherent bond on the surface of the matrix and fiber, protecting the fiber, separating the fiber, releasing the bond, and remaining stable after the manufacturing process.

Using of synthetic fibers as composite reinforcement has a negative impact on the environment because the waste cannot be decomposed naturally and can interfere with generations. The use of natural fibers as composite reinforcement is a wise step, considering that natural fibers can decompose naturally, and there are many kinds of natural fibers available such as jute fiber, pineapple fiber, palm fiber, coconut fiber, and others [14], [15].

Composite materials generally consist of two elements, namely fiber as a reinforcing material and resin as a fiber binding material. From this mixture, a composite material will be produced which has different mechanical properties and characteristics from the constituent material [16], [17].

In its development, the fibers used are not only synthetic fibers (fiberglass) but also natural fibers (natural fiber). Natural fiber composites have other advantages when compared to glass fiber, natural fiber composites are now widely used because of their large number, more environmentally friendly because they can be degraded naturally, and the price is cheaper than glass fiber. Weaknesses of natural fibers include the size of the fiber that is not uniform, the age of the fiber greatly affects its strength [18].

The smaller the diameter of the fiber, the greater the tensile strength, because the voids in the fiber are small and the intermolecular bonds are many, so the strength is strong. The larger the diameter, the smaller the tensile strength, because the voids in the fiber are large and the molecular bonds are few, so the tensile strength is low.

The development of natural fibers as reinforcement for composite materials is very good considering the availability of natural fiber raw materials in Indonesia is quite abundant [19].

Some matrix materials can provide the required properties such as plasticity and toughness. The matrix used in the composite must be able to carry the load so that the fiber must be able to adhere to the matrix and be compatible between the fiber and the matrix, meaning that there is no disturbing reaction. In this study, the matrix used is a thermoset resin with an epoxy resin type.

2. METHODS

In the study, using straw fiber material with fiber sizes between 20 mm and 30 mm and epoxy resin as a fiber binder in the composite material, consisting of resin and hardener. The number of layers in each composite consisted of 2, 4, 6 layers with fiber volume fractions: 25%, 33% and 50%. For the bending test using the ASTM D790 standard, while the impact test using the ASTM E23 standard. Testing using Universal Testing Machine and Charpy impact machine.

3. RESULTS AND DISCUSSION

3.1 Bending Test

The bending test data that has been obtained is converted into a graphic form and accompanied by a discussion. The average bending strength of the straw fiber composite with polyester matrix is shown in Figure 1.

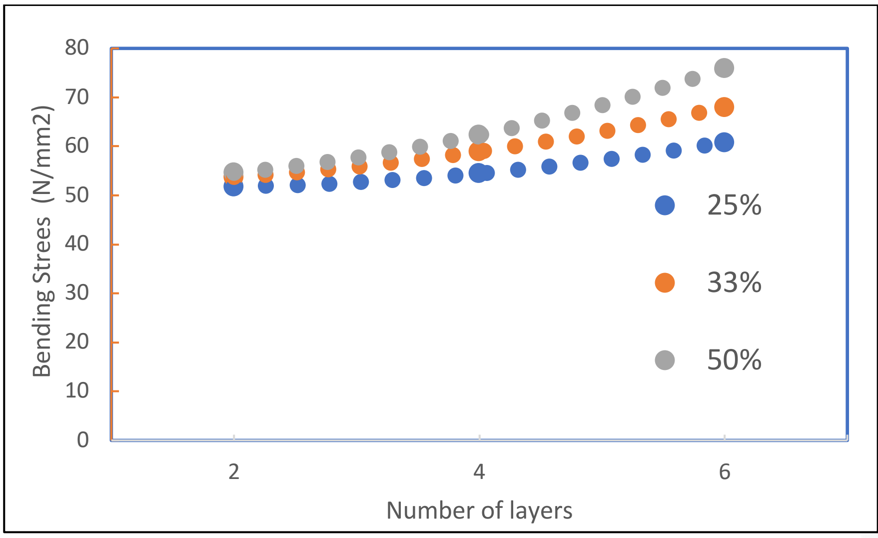

Figure 1 Relationship of Bending Stress with Number of Layers in several volume fractions.

In Figure 1 it can be seen that the bending strength of the straw fiber composite with 6 layers has an increasing trend as the number of piles increases because the matrix is able to bind straw fibers optimally as the number of piles increases. The highest bending strength with the number of piles of 6 layers and the lowest strength with the number of piles of 2 layers. In addition, the volume fraction is very influential on the bending stress of the straw composite matrix. It can be seen that the matrix with a volume fraction of 50% has the greatest bending stress in each layer, either 2, 4 or 6 layers. This is because the matrix is able to bind the fiber well, for the number of layers 4 and 6, when it reaches the highest bending stress it does not break immediately but cracks first, in addition to the straw fiber composite material with the number of layers 4 and 6, it is not easily deformed. compared to other materials. This is because the increase in the number of layers of straw fiber results in fiber density in the mold, so that the distribution of resin in the mold is more optimal and causes higher bending stresses. This means that as the number of layers increases, the composite material becomes more ductile. This can be seen in the strain graph of the straw fiber composite shown in Figure 2.

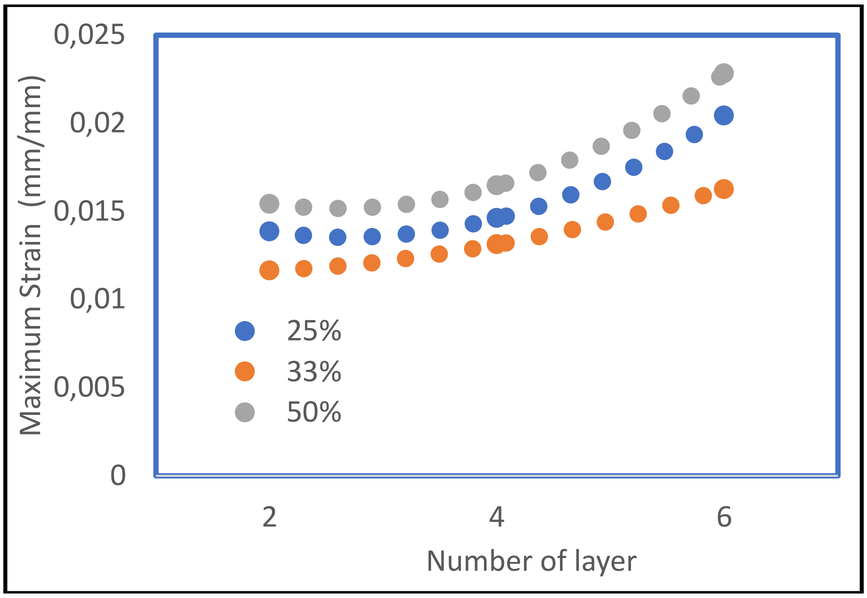

Figure 2. Relationship of maximum strain to the number of layers
in several volume fraction variations.

In Figure 2 it can be seen that the highest bending strain is found in the composite of 6 layers of fiber piles, this is because the composite material is a polyester matrix that is able to bind fibers optimally which is different between the other 2 materials. This is because the increase in the number of piles results in fiber density in the mold, so that the distribution of resin in the mold is more optimal which causes higher bending strength. In addition, the composite matrix with 6 layers is more ductile and before it breaks it undergoes a cracking process.

3.2 Impact Test

Impact testing data that has been obtained is converted into graphic form and accompanied by a discussion. The average impact test of the straw fiber composite with a polyester matrix is shown in Figure 3.

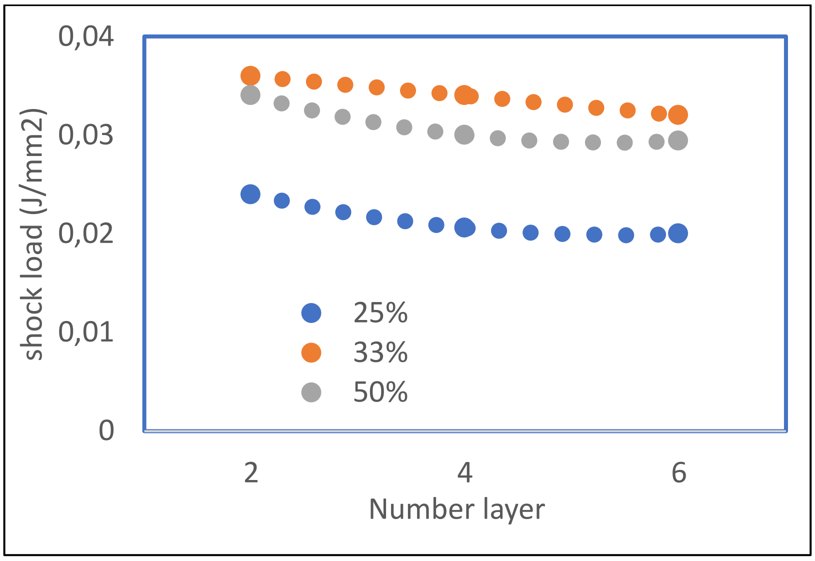

Figure 3 The relationship between the number of layers of straw fiber and the shock load in several volume fractions.

Based on Figure 3, the results of the impact test show that the optimal number of layers occurs in the number of 2 layers with a volume fraction of 33%. From the graph, it can be seen that the shock load increases from 2 layers to optimal at 4 layers and then tends to decrease. Meanwhile, based on the volume fraction, the larger the volume fraction, the smaller the shock load that this composite material can accept. According to [20], [21] that with a fixed amount of resin and more fiber or laminar fractions, the strength of the composite material will increase. This proves that the magnitude of the shock load (impact) decreases consistently with the addition of the volume fraction after 33%, while the optimal shock load occurs in the number of layers of 2 layers. This has the same tendency as the bending test, that an increase in the impact load only occurs in the volume fraction of 33%. While the decrease in the graph occurs in the volume fraction of 50% and 25%, along with the addition of the matrix composition. This phenomenon also proves that the matrix composition in this case is the ratio of resin and straw fiber gives an important role in the composite material, where the more resin composition compared to straw fiber will reduce the strength/toughness of the impact. In addition, there is a difference in the thickness of the styrofoam core with the increase in the number of layers that affect the mechanical properties of the structure of this composite material.

3.3 Structure of Fiber and Matrix Bonds

Whether or not the structure of the bond between fiber and matrix is good, one of them can be seen in the fracture results of mechanical testing.

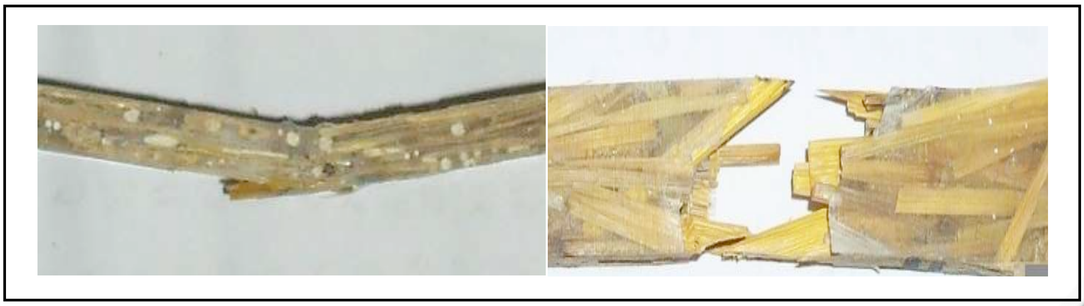

Figure 4 fracture results of mechanical testing

4. CONCLUSION

After analyzing and calculating the data and test results about the effect of variations in the length of straw fiber on the straw-epoxy composite material, it can be concluded, among others:

1. The bending strength of straw fiber composites with 6 layers has an increasing trend as the number of layers increases because the matrix is able to optimally bind straw fibers as the number of piles increases. The highest bending strength with the number of piles of 6 layers and the lowest strength with the number of piles of 2 layers.

2. In addition, the volume fraction is very influential on the bending stress of the straw composite matrix. It can be seen that the matrix with a volume fraction of 50% has the greatest bending stress for each number of layers, either 2, 4 or 6.
3. For the impact test, it was found that the optimal number of layers occurred in the number of 2 layers with a volume fraction of 33%. The shock load tends to decrease. Meanwhile, based on the volume fraction, the larger the volume fraction, the smaller the shock load that can be received by the straw fiber composite material.

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