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Development of Wind Turbine Blade Using Bamboo Fiber Composite Material

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Abstract. Wind turbines are power plants that utilize renewable energy. One of the essential parts in the development of wind turbines is the blade component. This study aims to compare the strength of wind turbine blades from bamboo composite materials with wind turbine blades using GFRP material. The data used in this study uses secondary data obtained from research that has been published in various journals. The research was carried out with software-assisted loading simulation. The strength of the blades is simulated using loads of 17.65 N, 20.59 N, and 22.555 N. Based on the simulation results, it can be concluded that the wind turbine blades made of bamboo fiber composite material have good strength. At light loads, the value of yield strength, shear strength, and safety factor can exceed the strength of water turbine blades made of GFRP. Wind turbine blades made of bamboo fiber composites have good potential to replace wind turbine blades made of GFRP. Keywords: Bamboo fiber composite materials, GFRP, wind turbine blades, simulation.

INTRODUCTION

Renewable energy is increasingly being developed to replace energy produced by fossils. One of the renewable energies that can be utilized is wind. In the early 2000s, wind began to become a preferred source of electricity generation [1]. The wind turbine can generate 318,105 MW worldwide. A wind turbine is one of the renewable energy producers utilizing wind as an energy source. Researchers try to create wind turbines that can produce large electrical power. Wind turbines have many components such as rotors, power transmission, generators, towers, and turbine blades or wind blades [1-4].

Initially, wind turbine blades were made of wood. Still, due to sensitivity to moisture and processing costs, modern materials such as glass-fiber-reinforced plastic (GFRP), carbon fiber-reinforced plastic (CFRP), steel, and aluminum are replacing wooden units. In the 19th century, wood was replaced with thin sheets of galvanized steel, and research was carried out on the behavior of metals for wind turbine applications. Galvanized steel is then abandoned because it has a high mass and low fatigue rate. Alloy steel is the optimal choice for turbine blades. Aluminum material is used but faces problems such as low fatigue resistance and high cost.

For this reason, the most widely used materials for wind turbine blades are composites, more specifically polymer matrix composites known as fiber-reinforced plastics (FRP). This composite combines two or more parts, namely matrix and fiber. The two combined parts form a useful material for turbine blade applications [3-8].

Bamboo in Indonesia is very abundant and has the potential to be developed into bamboo fiber-reinforced composite materials. However, bamboo is still rarely used to make manufactured products. Bamboo is easy to renew, fast in growth, and only takes three years to be harvested. Bamboo fiber has great potential to be used in natural fiber composites which are environmentally friendly, inexpensive, and lightweight. The selection of bamboo fiber as the primary material for research is due to the abundance of bamboo in Indonesia and the rare use of bamboo fiber for manufacturing products [4], [9-10].

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METHOD

The research method used is to simulate the loading of the wind turbine blades using software, with loads of 17.65 N, 20.59 N, and 22.555 N. As mechanical strength data, the researchers used data from analysis obtained from journal articles in the field of composite materials made from bamboo fiber. Simulations were carried out using the Autodesk fusion 360 application. The simulation results were further analyzed to determine the strength obtained and will be a reference in further research.

Simulation Preparation

The process of making the turbine blade design using fusion 360, with the following specifications:

Table 1. Specification of wind turbine blade [3-4]

Blade Length	115 mm
Blade Width	17 mm
Blade Thickness	2.1 mm
Blade Angle	5°
Hub Outer Diameter	28 mm
Hub Inner Diameter	8 mm
Thickness Hub	15 mm

FIGURE 1. Design of turbine blade

Simulation Process

The steps of the static stress simulation process using Autodesk Fusion 360 software are as follows:

a. Selection of simulation with static stress type.
b. This study used a polypropylene matrix composite material with a volume fraction of 90% and bamboo reinforcement with a volume fraction of 10%. Volume fraction is one way to determine the composition of a mixture with dimensionless quantity, mass fraction (mass percentage, wt%) and mole fraction (percentage by mole, mol%) [5], [10-12].

Table 2. Mechanical Properties of PP Composites with a volume fraction of 90% and Bamboo Composite Materials with a volume fraction of 10% [5]

1.	Density	931 kg/m^3
2.	Poisson Ratio	0.4
3.	Modulus Young	2.13 GPa
4.	Yield strenght	22.6 MPa
5.	Tensile strenght	35.21 MPa

In this study, the wind turbine blades will be given 3 loads, namely 17.65 N, 20.59 N, and 22.55 N.

RESULT AND DISCUSSION

The turbine blade design results are given a load by simulation using software with three loads, namely 17.65 N, 20.59 N, and 22.555 N. The given load refers to the reference used in this study [6], [13-16]. Based on the simulation results obtained safety factor, von mises, 1st principal, 3rd principal, and displacement.

Table 3. Safety factor simulation results

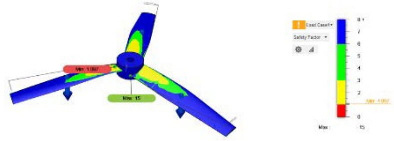
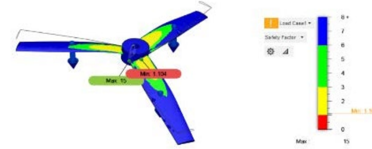
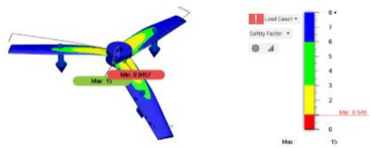
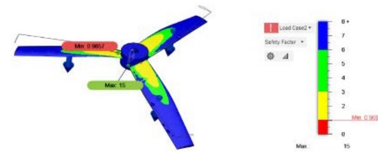
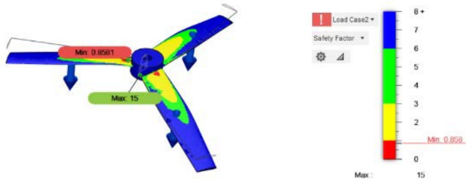
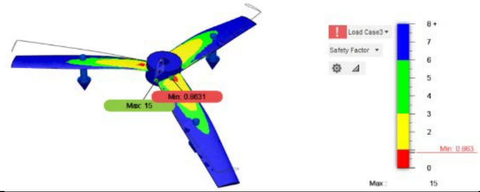
Load	Bamboo Composite Materials	GFRP Materials
17.65 N		
20.59 N		
22.555 N		

Table 4. Von Mises Simulation Results

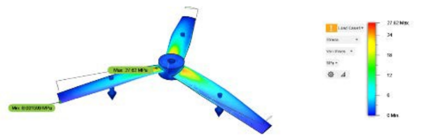
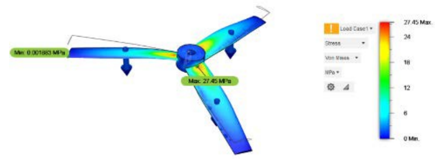
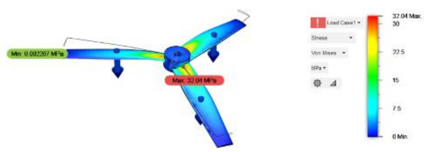
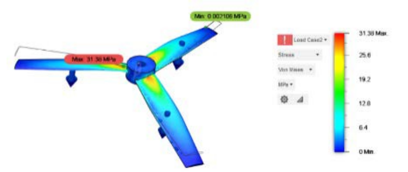
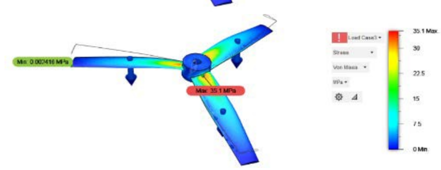
Load	Bamboo Composite Materials	GFRP Materials
17.65 N		
20.59 N		
22.555 N		

Table 5. 1st principal Simulation Results

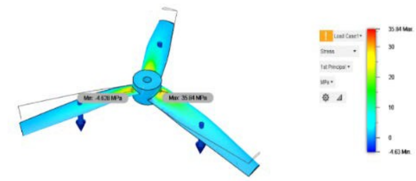
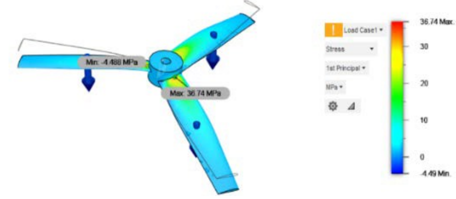
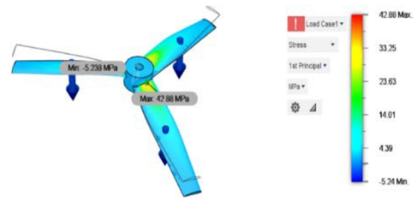
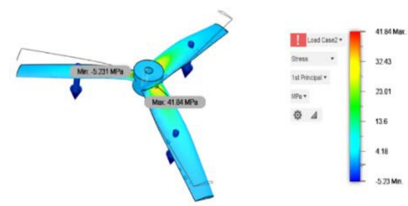
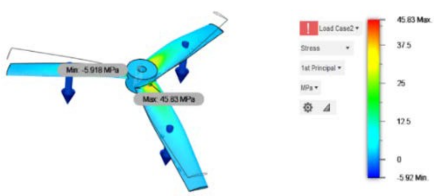
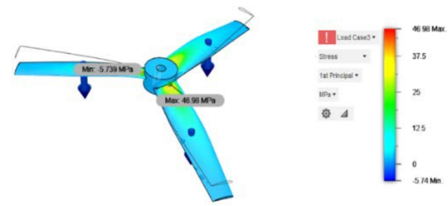
Load	Bamboo Composite Materials	GFRP Materials
17.65 N		
20.59 N		
22.555 N		

Table 6. 3rd Principal Simulation Result

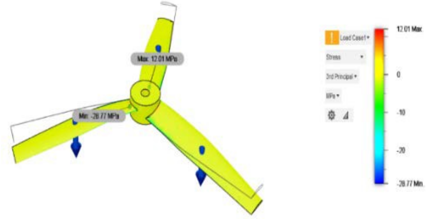
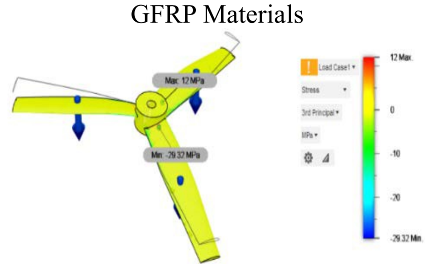
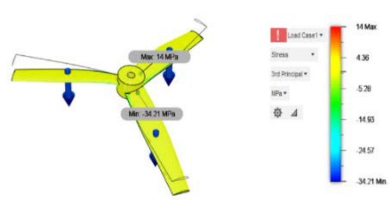
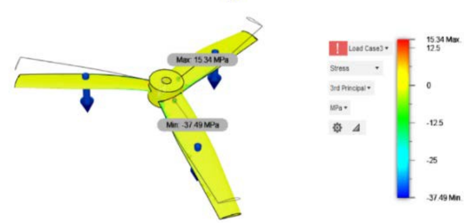
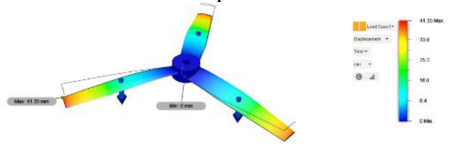
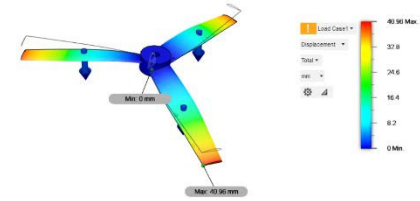
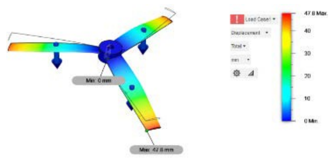
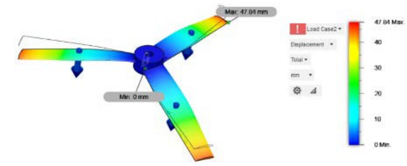
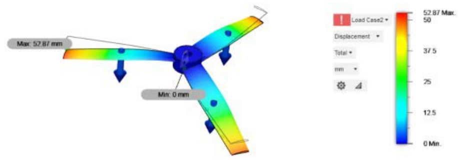
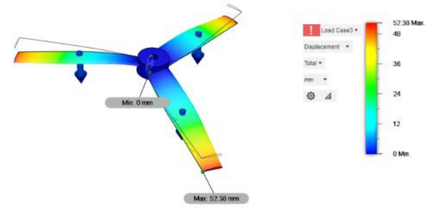
Load	Bamboo Composite Materials	GFRP Materials
17.56 N		
20.59 N		
22.555 N		

Table 7. Displacement simulation result

Load	Bamboo Composite Materials	GFRP Materials
17.56 N		
20.59 N		
22.555 N		

Research has been carried out to analyze the opportunities for bamboo fiber composite materials as an alternative material to make wind turbine blades. The analysis was carried out by making a blade design, modeling the load using software, then comparing the results of the analysis of wind turbine blades made of bamboo fiber composite material and GFPR material. Mechanical strength data utilizes secondary data that previous researchers from various journal articles have generated, then becomes input data in the analysis process using software assistance [14-16].

Based on tables 3, 4, 5, 6, and 7, the bamboo fiber composite material has good strength and can be further developed as an alternative material for making wind turbine blades. When viewed from the modeling of von Mises, the main stress, compressive stress, and displacement due to the load given in the simulation, it is seen that the bamboo fiber composite material produces characteristics that are close to the characteristics of the comparison material, namely GFPR. These results still need to be verified by physical testing and the manufacturing process of making wind turbine blade prototypes.

Physical testing using the applicable testing standards in the design of wind turbine blades can produce better recommendations and in accordance with the actual situation. Therefore, this research will be continued in the next stage, namely making prototypes and testing using a testing machine, so that the mechanical characteristics are close to reality. Testing of flexural strength, compressive strength, stiffness, and fatigue level is essential to be carried out. In the design, it is necessary to pay attention to the low mass, torsion resistance, and bending resistance. For composite materials, it is also necessary to ensure that there is no delamination and debonding so that strength is still obtained within a certain period to determine the lifetime [9-12].

CONCLUSION

The results of loading modeling using software on bamboo fiber composite materials and GFRP shows that safety factor, von mises, 1st principal, 3rd principal, and displacement at each loading of wind turbine blades made from bamboo fiber composites are close to those of turbine blades made from GFRP. Turbine blades made from bamboo fiber composites can be investigated further as an alternative material to replace GFRP blades. Prototyping and physical testing are required so that the actual characteristics of the wind turbine blades made of bamboo fiber composite materials can be obtained.

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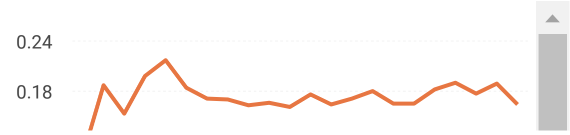

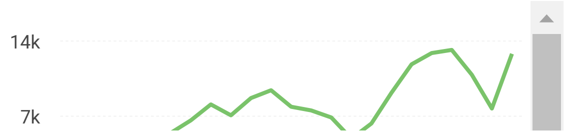

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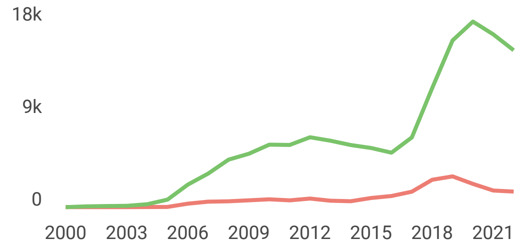

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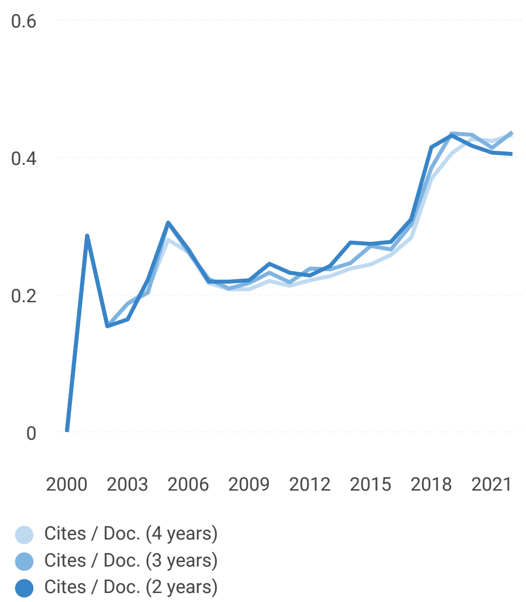

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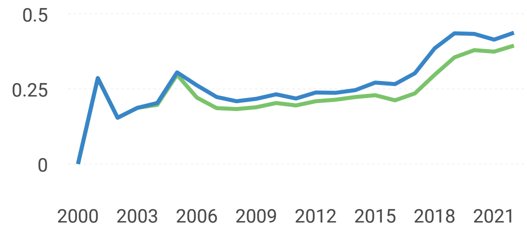

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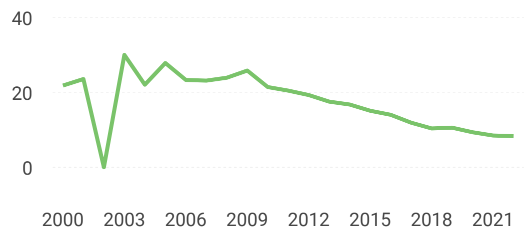

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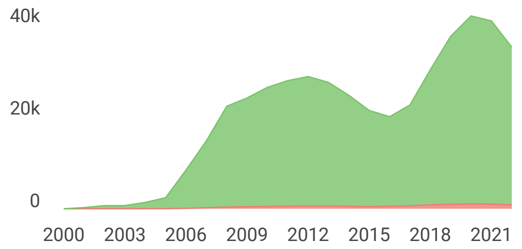

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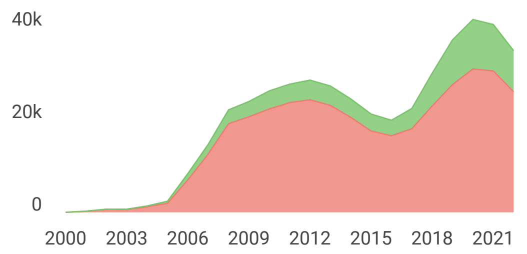

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