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Study Orientation Ply of Fiberglass on Blade Salt Water Pump Windmill using Abaqus

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Abstract. Windmill is one tool to generate energy from wind energy is converted into energy motion. Salt production process still using traditional process by utilizing windmill to move sea water to salt field. With a windmill driven water system, a horizontal axis type windmill with an average windmill height of 3-4 m, with a potential wind speed of 5-9 m/s, the amount of blade used for salt water pumps as much as 4 blades, one of the main factors of the windmill component is a blade, blade designed for the needs of a salt water pump by using fiberglass material. On layer orientation 0°, 30°, 45°, 60° and 90° with layer number 10 and layer thickness 2 mm, the purpose of this study was to determine the strength of fiberglass that was influenced by the orientation of the layer, and to determine the orientation of fiberglass layer before making. This method used Finite Element Analysis method using ABAQUS, with homogenous and heterogeneous layer parameters. The simulation result shows the difference in von misses value at an angle of 0°, 30°, 45°, 60° homogeneous value is greater than heterogeneous value, whereas in orientation 90 heterogeneous values have value 1.689e9 Pa, greater than homogenous 90 orientation value of 1.296e9 Pa.

1. Introduction

Windmill is one tool to generate energy from wind energy is converted into energy motion. Indramayu is one of salt producer in west java Indonesia, salt production process still using traditional process by utilizing windmill to move sea water to salt field with a windmill driven water system[1], a horizontal axis type windmill with an average windmill height of 3-4 m, with a potential wind speed of 5-9 m/s [2], the amount of blade used for salt water pumps as much as 4 blades, one of the main factors of the windmill component is a blade, a blade designed for the needs of a salt water pump by using fiberglass material.

Composite materials show different materials with materials in general, composite materials are strong fibers either in the form of continuous or noncontinuous surrounded by weak matrix materials. The matrix serves to distribute the fiber and also transmits the load to the fiber. Composite materials are not new, composite materials have been used since time immemorial. Composites have also been used to optimize the performance of some conventional weapons [3] [4] [5].

The purpose of this study was to determine the strength of fiberglass that was influenced by the orientation of the layer, and to determine the orientation of fiberglass layer before making. This method used Finite Element Analysis method using ABAQUS, with homogenous and heterogeneous layer parameters. In the blade-making process other than the thickness of the blade should be noted the effect...
of fiberglass layer orientation on the blade that aims to determine the strength of the blade when exposed to drag and lift force style. In this study, it is necessary to study the effect of fiberglass layer ornament on blade.

2. Method

![Flow Chart Methodology](image)

**Figure 1.** Flow Chart Methodology

The method of study in this paper is done by designing the blade first by using Computer Aided Design (CAD), then calculation of load due to wind load, then calculation simulation by loading and load parameters and material, simulation of blade strength calculation of orientation difference, Simulation of static strength of ply orientation is distinguished by homogeneous or heterogeneous type using ABAQUS software.

**Table 1. Property Material [4]**

| Material | Density $\rho$ ($kg/m^3$) | Modulus Elasticities $E$ (MPa) | Shear Modulus $G$ (MPa) | Ratio Poison | Tensile strength $\sigma$ (MPa) |
|----------|---------------------------|-------------------------------|------------------------|--------------|-------------------------------|
| E-Glass  | 2600                      | 74000                         | 30000                  | 0.25         | 2500                          |
| Epoxy    | 1200                      | 4500                          | 1600                   | 0.4          | 130                           |
Table 2. Characteristics Mechanic Fiberglass [4]

| Modulus Elasticity Longitudinal $E_l$ (MPa) | Modulus Elasticity Transversal $E_t$ (MPa) | Shear Modulus $G_s$ (MPa) | Ratio Poisson ($\nu$) |
|-------------------------------------------|------------------------------------------|--------------------------|---------------------|
| 46200                                     | 10309,6                                  | 3719                     | 0,31                |

3. Results and Discussion

a. Dimension of Blade

![Figure 2. Design of Blade](image)

Table 3. Dimension [2]

| Thickness (mm) | Material | Length (mm) | Wide (mm) | Ply |
|----------------|----------|-------------|-----------|-----|
| 2              | Fiberglass | 1000       | 145       | 10  |

b. Initial Condition

Blade design that has been made with CAD surface planar type, can be known big blade area to be made, with blade area (A) $130766,64 \text{ mm}^2$. To find out the magnitude of the force that occurs due to the wind speed and from the blade has a coefficient drag (CD) 2.3 with a wind type of 1,2 kg / $\text{m}^3$, it is possible to find a large drag force that occurs in the blade;

b.1 Minimal Velocity

$$F_{\text{drag}} = \frac{1}{2} CD \cdot \rho \cdot A \cdot v^2$$  
Eq.1 [2]

$$F_{\text{drag}} = \frac{1}{2} 2,3 \cdot 1,2 kg/m^3 \cdot 130257,73 \text{ mm}^2 \cdot 5^2 m/s$$

$$F_{\text{drag}} = 4,49 kg \approx 5 kg$$
b.2 Maximum Velocity

\[
F_{\text{drag}} = \frac{1}{2} C_D \rho A v^2
\]

\[
F_{\text{drag}} = \frac{1}{2} 2,312 kg/m^3 \cdot 130257.73 \ mm^2 \cdot 9^2 m/s
\]

\[
F_{\text{drag}} = 11.56 kg \approx 12 kg
\]

Figure 3. Initial Condition

In Figure 3 shows the initial condition, (a) shows the load on the blade surface due to the drag wind load, (b) denotes the meshing blade before it is calculated by ABAQUS.

c. Homogenous

In the calculation simulation using ABAQUS software, orientation is made with homogenous, at an angle 0°, with a maximum loading parameter of 12 kg, the following results are obtained:

Figure 4. Results of Orientation 0°

Figure 4 shows the simulation results of the calculations at homogeneous orientation, (a) the von mises value occurs at the maximum conditions at the pedestal area of 9.893e8 Pa, (b) The value of the strain 1.027e5 Pa, (c) the orientation direction of the homogeneous layer on Angle 0°.
Figure 5. Results of Orientation 30°

Figure 5 shows the simulation results of the calculations at homogeneous orientation, (a) the von mises value occurs at the maximum conditions at the pedestal area of 1,145e9 Pa, (b) The value of the strain 9,588e4 Pa, (c) the orientation direction of the homogeneous layer on Angle 30°.

Figure 6. Results of Orientation 45°

Figure 6 shows the simulation results of the calculations at homogeneous orientation, (a) the von mises value occurs at the maximum conditions at the pedestal area of 1,145e9 Pa, (b) The value of the strain 9,588e4 Pa, (c) the orientation direction of the homogeneous layer on Angle 45°.

Figure 7. Results of Orientation 60°
Figure 7 shows the simulation results of the calculations at homogeneous orientation, (a) the von mises value occurs at the maximum conditions at the pedestal area of 1,296e9 Pa, (b) The value of the strain 5,310e4 Pa, (c) the orientation direction of the homogeneous layer on Angle 60°.

\[ \text{Figure 8. Results of Orientation 90°} \]

Figure 8 shows the simulation results of the calculations at homogeneous orientation, (a) the von mises value occurs at the maximum conditions at the pedestal area of 1,120e9 Pa, (b) The value of the strain 2,655e4 Pa, (c) the orientation direction of the homogeneous layer on Angle 90°.

\[ \text{d. Heterogeneous} \]

\[ \text{Figure 9. Results of Orientation 0°,30°} \]

Figure 9 shows the simulation results of the calculations at heterogeneous orientation, (a) the von mises value occurs at the maximum conditions at the pedestal area of 1,120e9 Pa, (b) The value of the strain 2,655e4 Pa, (c) the orientation direction of the homogeneous layer on Angle 0°,30°

\[ \text{Figure 10. Results of Orientation 0°,45°} \]

Figure 10 shows the simulation results of the calculations at heterogeneous orientation, (a) the von mises value occurs at the maximum conditions at the pedestal area of 1,120e9 Pa, (b) The value of the strain 2,655e4 Pa, (c) the orientation direction of the homogeneous layer on Angle 0°,45°
Figure 10 shows the simulation results of the calculations at heterogeneous orientation, (a) the von mises value occurs at the maximum conditions at the pedestal area of 1,471e9 Pa, (b) The value of the strain 8,051e4 Pa, (c) the orientation direction of the homogeneous layer on Angle 0°,45°

Figure 11. Results of Orientation 0°,60°

Figure 11 shows the simulation results of the calculations at heterogeneous orientation, (a) the von mises value occurs at the maximum conditions at the pedestal area of 1,695e9 Pa, (b) The value of the strain 6,055e4 Pa, (c) the orientation direction of the homogeneous layer on Angle 0°,60°

Figure 12. Results of Orientation 0°,90°

Figure 12 shows the simulation results of the calculations at heterogeneous orientation, (a) the von mises value occurs at the maximum conditions at the pedestal area of 1,689e9 Pa, (b) The value of the strain 3,860e4 Pa, (c) the orientation direction of the homogeneous layer on Angle 0°,90°

Figure 13. Results Strain and Von Mises
Comparison of simulation results of strain and von mises calculation on homogenous and heterogeneous, in Figure 13 shows the graph of strain and von mises. (a) the value of strain shows at the angle 45°, 60°, 90° homogenous and heterogeneous condition have the same value, while at 30° has a value different, heterogeneous strain values, whereas (b) show the value of von mises at homogenous at oriented angle 0°, 30°, 45° has von mises value greater than von mises value in heterogeneous orientation, whereas at the angle of 90° heterogeneous von mises value more large compared to the value of homogenous von mises.

4. Conclusion
The result of simulation calculation using ABAQUS, on layer orientation 0, 30, 45, 60 and 90 with layer number 10 and layer thickness 2 mm, in homogenous and heterogeneous condition show the value of strain shows at the angle 45°, 60°, 90° homogenous and heterogeneous conditions have the same value, while at 30° has a value different, heterogeneous strain values, whereas (b) show the value of von mises homogeneous at oriented angle 0°, 30°, 45° has von mises value greater than von mises value in heterogeneous orientation, whereas at the angle of 90° heterogeneous von mises value more large compared to the value of homogenous von mises. Accordingly in the layer 90° orientation has the largest von mises value under heterogeneous conditions and has the lowest strain value and the same as the homogenous strain value.

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