Ply Thickness Fiber Glass on Windmill Drive Salt Water Pump

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Abstract. Factors management of salt-making processes need to be considered selection of the location and the season is very important to support the efforts of salting. Windmills owned by the farmers are still using wood materials are made each year it is not effectively done and the shape of windmills made not in accordance with the requirements without considering the wind speed and the pumping speed control influenced by the weight and size of windmill, it affects the productivity of salt. To optimize the function of windmills on pumping salt water by change the material blade on the wheel by using a material composite, composite or fiberglass are used for blades on windmills made of a material a mixture of Epoxy-Resin and Matrix E-Glass. The mechanical characteristics of the power of his blade one of determining the materials used and the thickness of the blade, which needed a strong and lightweight. The calculation result thick fiberglass with a composition of 60% fiber and 40% epoxy, at a wind speed of area salt fields 9 m/s, the drag force that occurs at 11.56 kg, then the calculation result by 0.19 mm thick with a layer of 10, the total thickness of 1.9 mm, with a density of 1760 kg/m\textsuperscript{3}, mechanical character of elongated elastic modulus of 46200 MPa, modulus of transverse elasticity of 1039.6 MPa, shear modulus of 3719 MPa and Poisson ratio of 0.31, then the calculation using the finite element ABAQUS obtained critical point at the confluence of the blade to the value of Von Mises tension was happening 1.158e9 MPa maximum and minimum 2.123e5 MPa, for a maximum value of displacement occurred condition at the tip of the blade. The performance test results windmills at a wind speed of 5.5 m/s wind power shows that occur 402.42 watts and power turbines produced 44.21 watt, and TSR 0.095 and the value Cp of 0.1, test results windmill in salt fields in the beginning rotation windmill lighter, able to move above wind speed of 5.5 m/s.

Keywords: Fiberglass, Weigth of Blade, Ply Thickness

1. Introduction
Indonesia is an agricultural country rich in marine resources, the development of the current era requires community to be more advanced and productive, especially in the field of food sourced from the sea, one of the food sources that currently have a high need is salt not only society but the need for food industry too high, needs high salt impact on the availability of salt was not able to be met due to the non-optimal management of salt fields and farmers have not been able to implement technology that is currently being developed [1].

Factors management of salt-making processes need to be considered selection of the location and the season is very important to support the efforts of salting. Windmills owned by the farmers are still using wood materials are made each year it is not effectively done and the shape of windmills made not in accordance with the requirements without considering the wind speed and the pumping speed control influenced by the weight and size of windmill, it affects the productivity of salt. To optimize the function of windmills on pumping salt water by change the material blade on the wheel by using a material composite, composite or fiberglass are used for blades on windmills made of a material a mixture of Epoxy-Resin and Matrix E-Glass. Based on this, there should be a study to optimize the function of windmills on pumping salt water by changing the raw material of blade on the wheel by using a material composite, composite or
fiberglass are used for blades on windmills made of a material a mixture of Epoxy-Resin and Matrix E-Glass. The advantages the research by reducing the weight of the blade turbines aims to windmills can be driven at low wind speeds, and is capable of moving the salt water pump to the optimum of power generated.

2. Methodology
Some steps has been done in the research as below;

![Flow chart of research steps](image)

Table 2.1 Property Materials [3]

| Material       | Density $\rho$ (kg/m³) | Modulus Elasticity $E$ (MPa) | Shear Modulus $G$ (MPa) | Poisson Ratio | Tensile Strength $\sigma$ (MPa) |
|----------------|------------------------|----------------------------|------------------------|---------------|-------------------------------|
| E-Glass        | 2600                   | 74000                      | 30000                  | 0.25          | 2500                          |
| Epoxy          | 1200                   | 4500                       | 1600                   | 0.4           | 130                           |

3. Result and Discussion

3.1. Calculation Thickness
The thickness of fiberglass done before Finite Element calculation as an initial condition for determining the thickness of the blade, the composition of the volume for the manufacture of blade 60% fiber volume of E-glass and 40% volume Epoxy as reinforcement, using the following equation;

$$ h = m_{of} \left[ \frac{1}{\rho_f} \frac{1}{\rho_f} \frac{(1-M_f)}{M_f} \right] $$

$m_{of} = 300$

$M_f = \text{Mass of fraction} = \frac{\text{Mass of fiber}}{\text{Mass of total}} = \frac{1560}{2040} = 0.76$

$\rho_f = \text{mass density of epoxy} = 1200 \text{ kg/m}^3$

Fiberglass blade thickness is obtained;

$$ h = 300 \left[ \frac{1}{1200} \frac{1}{1200} \frac{(1-0.76)}{0.76} \right] $$

$h = 0.19 \text{ mm}$
3.2. Mechanical characteristics of fiberglass

3.2.1. Modulus Elasticity

- Longitudinal

\[ E_l = E_f V_f + E_m V_m \]  

\[ E_l = \text{Modulus Elasticity of fiber} = 74000 \text{ MPa} \]
\[ V_f = \text{Volume fiber} 60\% \]
\[ E_m = \text{Modulus Elasticity of matrice epoxy} = 4500 \text{ MPa} \]
\[ V_m = \text{Volume matrice epoxy} 40\% \]

- Transverse

\[ E_t = E_m \left[ \frac{1}{(1-V_f) + \frac{E_m}{E_f}} \right] \]  

3.2.2. Shear Modulus

\[ G_{lt} = G_m \left[ \frac{1}{(1-V_f) + \frac{G_m}{G_{lt}}} \right] \]

3.2.3. Poisson Ratio

\[ v_{lt} = v_f V_f + v_m V_m \]
\[ v_f = \text{poisson ratio of fiber} = 0.25 \]
\[ v_m = \text{poisson ratio of matrice epoxy} = 0.40 \]

The calculation results percentage composition of epoxy and E-glass of material characteristics values obtained the material a mixture of in the following table;

| Modulus Elasticity Longitudinal | Modulus Elasticity Transverse | Shear Modulus G_s (MPa) | Poisson Ratio (v_lt) |
|-------------------------------|-----------------------------|----------------------|-------------------|
| 46200                         | 10399.6                     | 3719                 | 0.31              |

3.2.4. Modulus Any Direction

\[ E_x = \frac{c^2 s^2 + c^2 + 2c^2 s^2(1 - v_{lt})}{c^2 + s^2} \]

\[ c = \cos \theta \]
\[ s = \sin \theta \]
3.3. Mass Density of a Ply

The mass density of a ply can be calculated as:

\[
\rho_f = \text{mass density of epoxy} = 1200 \text{ kg/m}^3
\]
\[
\rho_m = \text{mass density of E-glass} = 2600 \text{ kg/m}^3
\]

\[
\rho = \rho_f V_f + \rho_m V_m
\]
\[
\rho = 1200 \times 0.6 + 2600 \times 0.4
\]
\[
\rho = 1760 \text{ kg/m}^3
\]

\[
m = v \rho
\]
\[
m = 130257,73 \text{mm}^2 \times 1,9 \text{mm} \times 1760 \text{ kg/m}^3
\]
\[
m = 0,0002475 \text{m}^3 \times 1760 \text{ kg/m}^3
\]
\[
m = 0,4356 \text{kg}
\]

The calculation result windmill weight of 0.4356 kg with a thickness of 1.9 mm, while the results have been made windmill has weight with a thickness of 2 mm, has a weight of 0.510 kg.

3.4. Finite Element

3.4.1. Design

In the process of finite element calculations need to be done with the input initial conditions, a thickness of 0.19 mm on each layer, the angle between the longitudinal and transverse layers of 0 ° and 90 ° with the character input material as shown in Table 1, it can be seen that the calculation results of the styles caused by wind speed, with the observation of the fields salt that occurred maximum wind speed of 9 m / s.

Figure 3.2 Design Blade of Windmill

The design of the blade that was created with CAD-type planar surface, with a length of 1m and a the blade that will be created, with an area (A) 130,766.64 mm².
To know the great value of the force caused by wind speed and on the shape of the blade has a coefficient of drag (CD) 2.3 and the air density of 1.2 kg / m³, then can be searched large drag force that occurred on the blade:

\[ F_{\text{drag}} = \frac{1}{2} C_D \rho A v^2 \]  \hspace{1cm} (9)

\[ F_{\text{drag}} = \frac{1}{2} 2.3 \times 1.2 \text{kg/m}^3 \times 130257.73 \text{mm}^2 \times 9^2 \]

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

Then the pressure on the blade of a windmill:

\[ P = \frac{F}{A} \]  \hspace{1cm} (10)

\[ P = \frac{12 \text{ kg}}{130257.73 \text{ mm}^2} \]

\[ P = 92.125 \text{ kg/m}^2 \approx 921.25 \text{ N/m}^2 \]

3.4.2. Initial Condition

![Figure 3.3 Initial Condition and Meshing](image)

3.4.3. Result

![Figure 3.4 Result Stress Von Mises](image)

Results of the finite element calculations using ABAQUS, the maximum voltage happened as a result of pressure loading occurs at the point of retaining a large hole with a maximum value 1,158e9 MPa, and minimal 2,123e5 MPa occur at the end of the the blade.
In the visual image above shows the results of displacement maximum value occurs at the end of the windmill blade.

Finite element calculation results of Figure 3.6, shows the maximum value in the area close to the pedestal, with a maximum value and minimal $-1.516 \times 10^3$ $4.362 \times 10^{-4}$ MPa MPa, compared with the value that occurs in finite element calculation of the maximum values happened less than the value of the calculation of elasticity at an angle $0^\circ$ of $46200$ MPa.

In the figure above shows the direction of angle E-glass on the blade and the many layers of the calculation results are shown in figure 0.19.
3.5. Build Windmill

The process of manufacture and assembly of blades on a windmill, then conducted laboratory testing and installation of windmill in the salt fields, test results windmill in salt fields in the beginning rotation windmill lighter able to move above wind speed of 5.5 m/s.

![Figure 3.6 Build and Assembly windmill](image)

3.6. Test Performance

3.6.1. Tip Speed Ratio (TSR)

A comparison between the speed at the tip of the blade to the wind speed through it. Can be in the know by using the equation;

$$\lambda = \frac{\Omega R}{V}$$

where:

- $\Omega = \frac{\pi}{60} = 0.523$
- $R = 0.523 \times 1$
- $V = 6.28$

$$\lambda = \frac{0.523 \times 1}{6.28} = 0.095$$

The calculation of the value of the Tip Speed Ratio is 0.095 of the value 0.095<1 refers to the Betz law, then the more experienced the blade thrust.

3.7. Air Power

$$P_{angin} = \frac{1}{2}, \rho, A, v^3$$

Dimana: $P$= Air Power (watt)
- $\rho$= Density of Air ($kg/m^3$)
- $A$= Areawindmill ($m^2$)
- $v$= Air Velocity (m/s)

to look for wide sweep of the turbine rotor the blade can use the following formula;

$$A = \frac{\pi}{4} \cdot d^2$$

Maka : $A = \frac{3.14}{4} \cdot 2.22^2$
$$= 3.87 \ m^2$$

Obtained a sweep area of the rotor with a diameter of 2.22 meters which is 3.87 m$^2$.

$$P_{angin} = \frac{1}{2} \cdot 1.25 \ kg/m^3 \cdot 3.87 m^2 \cdot (5.5)^3 m/s$$
$$= 402.42 \ watt$$
From the above calculation, the wind power generated at wind speed of 5.5 m/s is at 402.42 watts.

3.8. Windmill Power

Calculation the windmill power can use the equation;

\[ P_{\text{kincir}} = T \cdot \omega \]  

(14)

Dimana : \( T = \text{torque} \) (Nm)  
\( \omega = \text{blade speed} \) (rad/s)

then torque of the test results that occur when wind speed of 5.5 m/s of 3.84 Nm. As for the seek values blade velocity (\( \omega \)) can use the following equation;

\[ \omega = \frac{2 \cdot \pi \cdot n}{60} \]  

(15)

where: \( n = \text{shaft rotation (rpm)} \)

test results kecapatan windmill with 5.5 m/s is obtained value of rotation 110 rpm.

\[ \omega = \frac{2.314 \cdot 110}{60} = 11.51 \text{ rad/s} \]

From the above calculation, the power generated by the windmill shaft rotation speed of 110 rpm is at 11.51 rad/s.

the values of that have been is obtained over the windmill power can be calculated as follows;

\[ P_{\text{kincir}} = T \cdot \omega \]

\[ P_{\text{kincir}} = 3.84 \text{ Nm} \cdot 11.51 \text{ rad/s} = 44.21 \text{ watt} \]

From the above calculation, the power generated by the windmill torque of 3.84 Nm is at 44.21 watts.

3.8.1. Calculation Coefficient Power (Cp)

To calculate the value of Cp can be calculated using the equation;

\[ Cp = \frac{P_{\text{windmill}}}{P_{\text{air}}} \]  

(16)

\[ Cp = \frac{44.21 \text{ watt}}{402.42 \text{ watt}} \]

\( Cp = 0.1 \)

Test operation of the windmill can be said TSR value of 0.095, and the value Cp of 0.1

4. Conclusion

The calculation result thick fiberglass with a composition of 60% fiber and 40% epoxy, at a wind speed 9 m/s, the drag force that occurs by 112 kg, then the calculation result by 0.19 mm thick with a layer of 10, the total thickness of 1.9 mm, with a density of 1760 kg/m³, with a mechanical character of the modulus of elasticity of 46200 MPa longitudinal, transverse elasticity modulus of 10309.6 MPa, shear modulus of 3719 MPa and Poisson ratio of 0.31, then calculate by using ABAQUS finite element obtained at the critical point pedestal portion of the blade to the value of Von Mises tension was happening 1.158e9 MPa maximum and minimum 2.123e5 MPa, for a maximum value of displacement occurred condition at the tip of the blade. The elasticity happens calculation results have a greater value than the simulation results by using ABAQUS finite element, the performance test results windmills at a wind speed of 5.5 m/s wind power shows that occur 402.42 watts and power turbines produced 44.21 watt, and TSR 0.095 and the value Cp of 0.1, test results windmill in salt fields in the beginning rotation windmill lighter, able to move above wind speed of 5.5 m/s.

Recommendations

At the of fiberglass blade the critical point happens to be able to distinguish the foundation thickness at that point thicker or with a better composition in order to reduce the the critical point happened and some other variables such as the blade angle and sweep an area that affects windmills windmill

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