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Design of Tapperless Type Horizontal Axis Wind Turbine (Hawt) Blades using Mahogany Wood Material

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Abstract. *Indonesia has quite large wind energy resources spread across various regions, so it has the potential to be developed into PLTB. Energy needs in Indonesia continue to increase and the government is committed to utilizing new, renewable energy to achieve emission reduction targets. However, efforts to utilize wind energy are still not optimal due to several reasons, especially research and research capabilities related to PLTB. The blade is the main component in the wind turbine system and is the system that first receives the wind and then converts it into mechanical energy. This research aims to determine the performance and manufacture tapperless type wind turbine blades with NREL's S822 airfoil using Qblade and Solidworks software. The design and simulation results show that the resulting blade has a blade radius of 1 meter, a blade or chord width of 0.12 m. The twist angle from the base to the tip of the blade ranges from 11.69º to 5.05º and a power of 500 W is obtained at a rotational speed of 262 rpm*.

Keywords: *Wind, Blade, Tapperless, Airfoil, Qblade, Solidworks*

INTRODUCTION

Wind energy has two opposite sides. On the one hand, the destructive side, wind can be a disaster for human life, such as tornadoes and typhoons. However, on the other hand, wind can be a source of kinetic energy to move wind turbine blades so that it can produce electrical energy for human life. We can see this in various countries that have made extensive use of wind power plants (PLTB), such as China, the United States and Germany, which have fairly strong and regular winds over a long period of time (Rahmat M., H, 2017).

Indonesia itself also has wind energy resources which are quite large and spread across various regions to be developed into PLTB. According to research results from the National Institute of Aeronautics and Space (LAPAN), of the 166 locations studied, there were 35 locations that had good wind potential with wind speeds above 5 meters per second at a height of 50 meters. Areas that have good wind speeds include West Nusa Tenggara (NTB), East Nusa Tenggara (NTT), the south coast of Java and the south coast of Sulawesi. Apart from that, LAPAN also found 34 locations where the wind speed was sufficient at 4 to 5 meters per second (Energinet, DEA, 2016).

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The Indonesian government itself, through the Directorate General of EBTKE, has committed to utilizing new and renewable energy by preparing a strategic plan and this effort is also being taken by Indonesia to achieve the target of reducing emissions and Net Zero Emission (carbon neutrality) which is targeted to be achieved in 2060 or earlier (Ministry of Energy and Mineral Resources, 2021).

However, the Indonesian government's efforts to utilize wind energy are still not optimal due to several reasons, such as there are many potential locations that have not been utilized, have not been identified, have not been measured and are far from load centers and wind turbine technology and the domestic market for small scale wind turbines has not yet developed. Based on these problems, this research will design a Tapperless type Horizontal Axis Wind Turbine (HAWT) blade using NREL's S822 Airfoil airfoil and will be manufactured using mahogany wood (swietenia macrophylla).

METHODS

The following is a flow diagram for the tapperless type Horizontal Axis Wind Turbine (HAWT) blade design starting with literature studies and observations through to the manufacturing process:

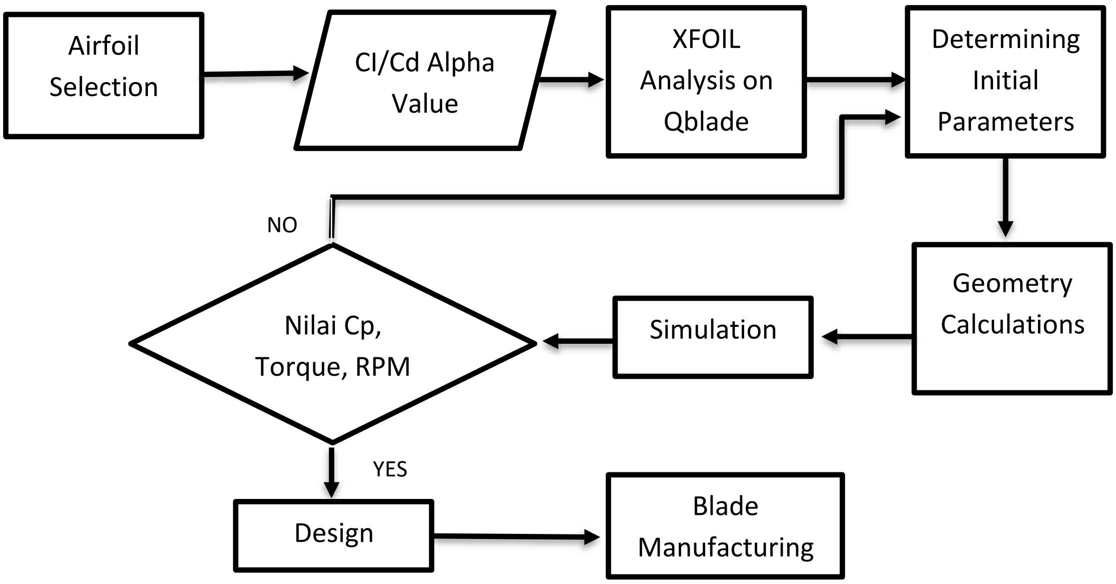

Figure 1. Blade Build Design Flow Diagram

RESULTS

Planning Outcome Data

The design data is obtained through calculations based on known generator specifications:

System Name	TSD-500
Turbine Type	HAWT
Maximum Power Output	500 Wp at 12 m/s above
Start up Wind Speed	2.5 m/s
Cut in Wind Speed	3 m/s
Survival Wind Speed	33 m/s
Generator Type	3-phase permanent magnet (Cogging-less technology)
Blade Diameter	1.6 and 2 m
Number of blades	3 blades
Blade Material	Pinewood
Maximum RPM	1000 RPM
Storage System	24 V
Weight of Turbine System (except pole)	25 kg
Height of Pole	4 - 6 m
Manufactured by	Nidec Corp. Japan

Figure 2. Generator Specification Data

Initial Parameters

In determining the initial parameters there are several data that have been determined based on specifications and field studies as in the table:

Table 1. Data on power capacity, component efficiency and maximum wind speed

Electric Power Capacity (We)	Efficiency				Vmax
	Blade	Transmission	Generator	Controller	
500	0.3	0.9	0.9	0.9	10
	0.4				

System efficiency is calculated

1. Assuming the maximum and minimum blade efficiency values based on the table:

$$K_{minimum} = \eta_{blade} + \eta_{transmission} + \eta_{generator} + \eta_{controller} = 0.3 + 0.9 + 0.9 + 0.9 = 0.22$$

$$K_{maximum} = \eta_{blade} + \eta_{transmission} + \eta_{generator} + \eta_{controller} = 0.4 + 0.9 + 0.9 + 0.9 = 0.29$$

2. The required wind power is determined:

$$W_{a\ minimum} = \frac{W_e}{K} = \frac{500}{0.22} = 2.286$$

$$W_{a\ maximum} = \frac{W_e}{K} = \frac{500}{0.29} = 1.715$$

3. The swept area is determined:

$$A_{minimum} = \frac{2W_a}{\rho V_{max}^3}$$

$$A_{minimum} = \frac{2\ x\ 2.286}{1.225\ x\ 10^3} = 3.732\ m^2$$

$$A_{maximum} = \frac{2\ x\ 1.715}{1.225\ x\ 10^3} = 2.8\ m^2$$

4. The radius can be determined :
5. Based on the radius calculations above, the radius used for this study is determined to be 1 meter.
6. The tip speed ratio is determined based on the table below:

Table 2. Tip Speed Ratio for Various Blade Numbers

λ	**1**	**2**	**3**	**4**	**5-8**	**8-15**
B	6-20	4-12	3-6	2-4	2-3	1-2

7. Based on the above calculations, the initial parameters can be summarized in the following table:

Table 3. Initial Parameter Calculation Results

Efficiency	Wind Power (W_a)	Efficiency (A)	Wind Power (R)	Efficiency
0.22	2,286	3.732	1.09	1
0.29	1,715	2.8	0.94	1

DISCUSSION

Once all the data is known, the next step is to enter it into the Qblade software to carry out the initialization process so that the simulation results can be obtained and can be analyzed:

	Pos (m)	Chord (m)	Twist	Foil	Polar
1	0	0.12	8.392	NREL's S822 Airfoil	T1_Re0.600_M0.00_N9.0 360 M
2	0.083	0.12	8.041	NREL's S822 Airfoil	T1_Re0.600_M0.00_N9.0 360 M
3	0.166	0.12	7.691	NREL's S822 Airfoil	T1_Re0.600_M0.00_N9.0 360 M
4	0.249	0.12	7.341	NREL's S822 Airfoil	T1_Re0.600_M0.00_N9.0 360 M
5	0.332	0.12	6.991	NREL's S822 Airfoil	T1_Re0.600_M0.00_N9.0 360 M
6	0.415	0.12	6.641	NREL's S822 Airfoil	T1_Re0.600_M0.00_N9.0 360 M
7	0.498	0.12	6.29	NREL's S822 Airfoil	T1_Re0.600_M0.00_N9.0 360 M
8	0.581	0.12	5.94	NREL's S822 Airfoil	T1_Re0.600_M0.00_N9.0 360 M
9	0.664	0.12	5.59	NREL's S822 Airfoil	T1_Re0.600_M0.00_N9.0 360 M
10	0.747	0.12	5.24	NREL's S822 Airfoil	T1_Re0.600_M0.00_N9.0 360 M
11	0.83	0.12	4.89	NREL's S822 Airfoil	T1_Re0.600_M0.00_N9.0 360 M

Figure 3. Input data to Qblade software

Figure 3.8 shows a 3D image of the blade in Qblade software:

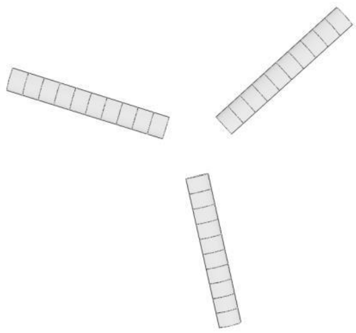

Figure 4. 3D image in Qblade software

Relationships Cl/Cd Against Alpha

Simulation results on Qblade show that the NREL airfoil characteristics have the highest Cl/Cd value of 104.91 at Alpha 5° as shown in the figure:

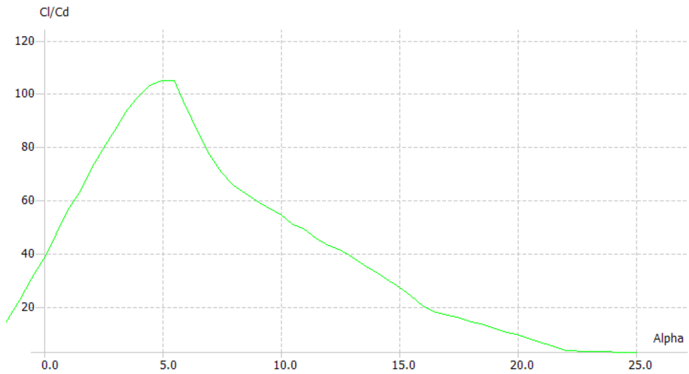

Figure 5. Graph of the relationship between Cl/Cd and Alpha

The greater the Cl/Cd value indicates the greater the efficiency value of the blade. The Cl/Cd value is also influenced by the Reynolds number used, the higher the Reynolds number, the higher the Cl/Cd value of the airfoil.

Relationship of Power to Rotational Speed

The simulation results on the Qblade show that 500 watts of power is obtained at 262 rpm. After the power reaches the maximum point, the power will decrease slowly as the rotational speed increases.

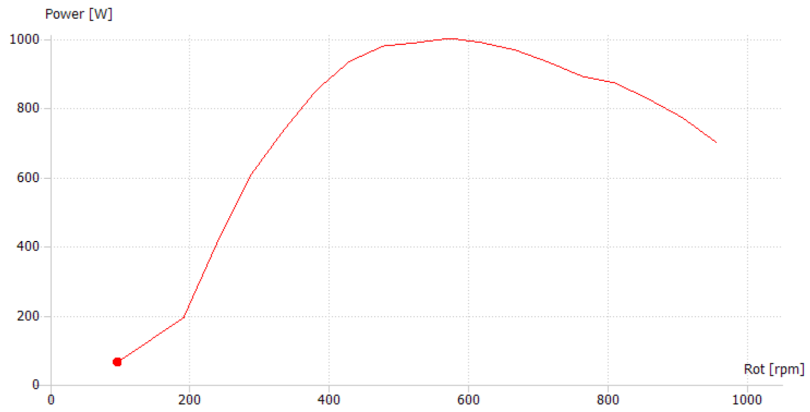

Figure 6. Graph of the relationship between Power and Rotational Speed

Relationships Cp Against TSR

The simulation results on Qblade show that the largest coefficient power value is 0.52 at TSR 6 as shown in the figure:

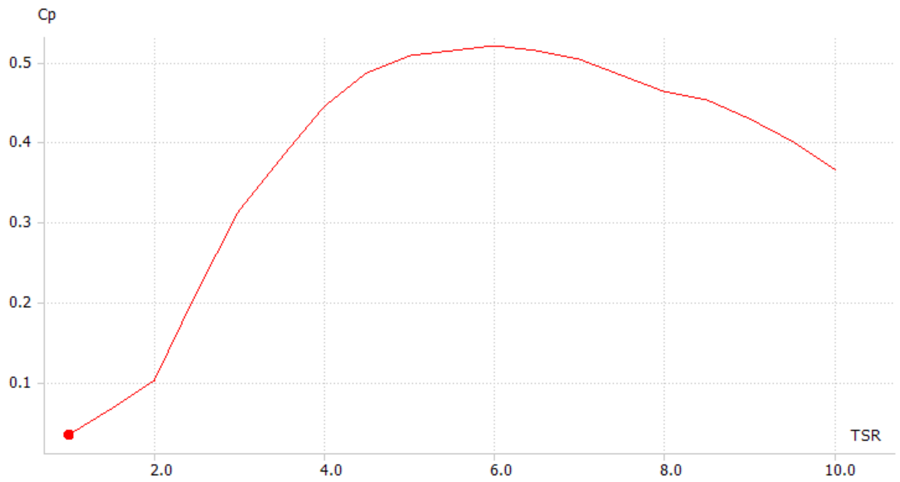

Figure 7. Graph of the relationship between Cp and TSR

Based on Betz theory, it can be seen that the maximum efficiency of a conventional wind turbine is 0.59 and based on the graphical image of the results

The simulation shows that the resulting Cp is 0.52, which means that the designed wind turbine blade has a good ability to extract wind energy.

Relationships Cp Against Rotational Speed

The simulation results on Qblade show that a maximum Cp value of 0.52 is produced when rpm is 570 as shown in the picture:

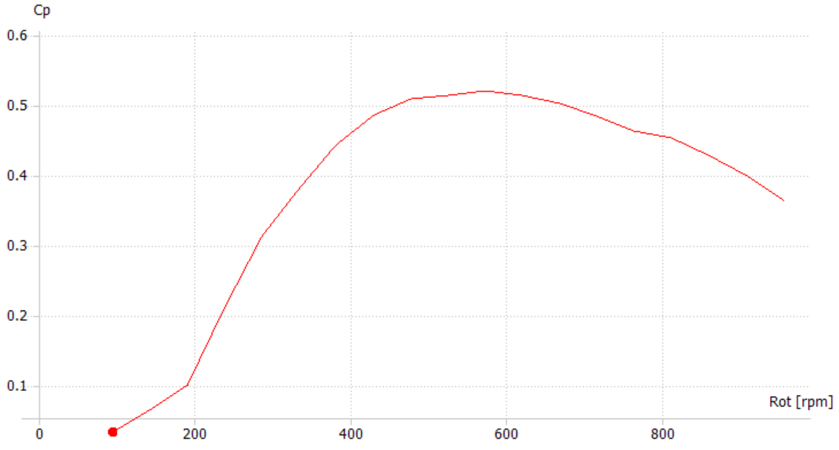

Figure 8. Graph of the relationship between Cp and rotational speed

Relationship between torque and rotational speed

The simulation results on the Qblade show a torque value of 21 Nm at rpm 381. Next, the torque will slowly decrease, this happens because the high rotation makes the fluid friction force large, while the force required by the rotating wind turbine blade remains constant.

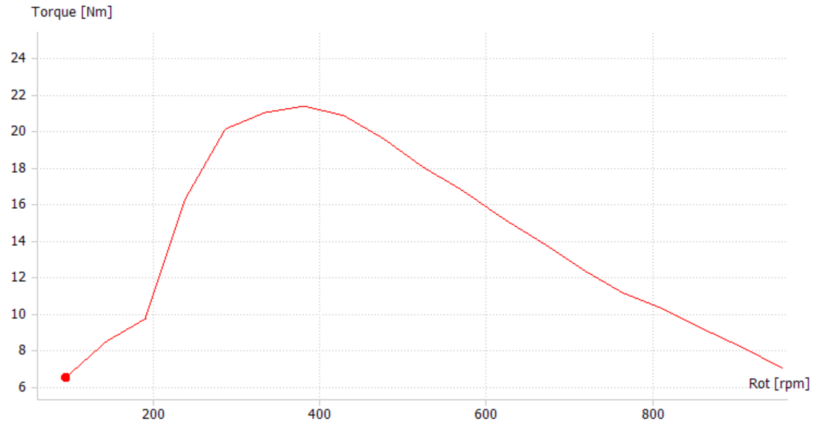

Figure 9. Graph of the relationship between torque and rotational speed

CONCLUSION

The results of the design and manufacturing show that the Tapperless type Horizontal Axis Wind Turbine (HAWT) using NREL's S822 airfoil has a blade radius of 1000 millimeters, a blade or chord width of 120 millimeters and a height of 260 millimeters. The twist angle from the base to the tip of the blade ranges from 11.69º to 5.05º. The average weight of the blade is 1.2 kg.

Simulation results of the Horizontal Axis Wind Turbine (HAWT) type Tapperless using NREL's S822 airfoil showed a power of 500 W at a rotational speed of 262 rpm, a Cp of 0.52 at a rotational speed of 570 rpm, a maximum torque of 21 Nm at an angular speed of 381 rpm.

The manufactured wind turbine blade has been installed on a 1 meter generator and upon inspection there is quite a large vibration caused by the length and weight of the large blade so that it cannot be installed and aired on a 5m tower to obtain test data.

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