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Designing of Inverse Taper Wind Turbine Blade for Pekanbaru Wind Speed Condition

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ABSTRACT

Wind energy as one of renewable energy resource has a great potential to solve the problem of dependency on fossil fuels, especially in Pekanbaru, Indonesia. Pekanbaru wind speed condition which is considered relatively low can be harnessed efficiently by designing blades which suits wind condition in Pekanbaru. Blades are designed using aerodynamic equations and software assistance such as Microsoft Excel, Qblade, and Autodesk Inventor. As a result, the blades can generate mechanical power at low wind speeds with a radius 1.1 m and hub 0.2 m and the chord length at the base of the blade 0.13 m and at the tip 0.26 with twist angle at the base of the blade 20.4 ・ and at the tip 5.6 ・. The result of this research is to show that the inverse taper blade design is applicable in low wind speed conditions in order to produce an affordable, compact, and efficient wind turbine appropriate for wind characteristic in Pekanbaru.

KEY WORDS: *Chord, Twist Angle, Inverse Taper, Wind Turbine*.

NOMENCLATURE

C_p	Power Coefficient
C_r	Chord
P_e	Nett Power
C_{PD}	Blade Efficiency
η_T	Transmission Efficiency
η_g	Generator Efficiency
V_{max}	Maximum Wind Velocity
λ	Tip Speed Ratio
B	Blade Number
ρ_{air}	Air Density

1.0 INTRODUCTION

Lack of fossil fuel as energy resource of world triggers a rapid development in renewable energy. Wind energy as one of renewable energy resource has a great potency to solve energy needs. Nevertheless, the application of wind energy technology is remain undone.

Indonesia is a vast country and consists of many islands resulting in different wind characteristics in each region. In Pekanbaru, the highest average monthly wind speed in the period 2011 to 2015 occurred in June 2012 that is 3.6 m/s as shown in Figure 1.

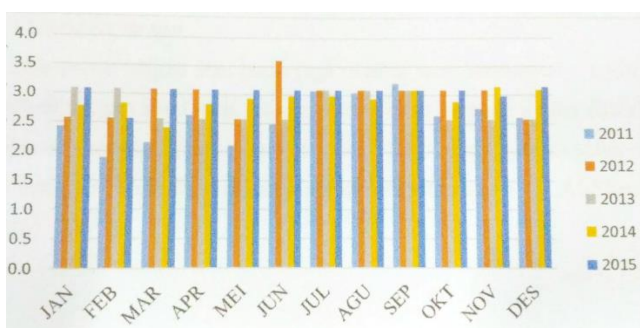

Figure 1: Average Monthly Wind Speed in the Period 2011-2015 in Pekanbaru (BMKG Pekanbaru City)

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In order to extract this energy generated in relatively low wind speed condition, we have to design a wind turbine appropriates for corresponding condition. Therefore, in order to achieve this objective, various optimizations can be conducted on several wind turbine components, one of the important components to be is the blade. By designing a suitable blade and optimizing blade efficiency, we can create a wind turbine system suits for Indonesia wind characteristics.

2.0 METHODOLOGY

The turbine used in this research was Horizontal Axis Wind Turbine (HAWT) type consisting rotor system with 5 inverse taper type blades, which the inversely tapered blades increase the power coefficient with the number of blades than normally tapered blades [1]. The blades was designed using various aerodynamic calculations and numerical methods. The blade design was obtained by using aerodynamic calculations [2] and software assistance such as Microsoft Excel to obtain the geometry and QBlade to get its characteristics and performance. The design procedures were divided into several steps, i.e. geometry specification and 3 dimensional modelling. The geometry calculation results showed that the blade which radius and hub length were 1.3 m and 0.2 m used Styrofoam as material because its high value stiffness to weight ratio and a rectangular hollow stainless steel with 1 m in length and 40 x 10 mm in cross area to strengthen its structure resulting. The blade use NACA 4412 aerofoil because it has a high value of C_L/C_D (120) [3] which results in compatibility with wind turbine which operates by harnessing lift force (C_L) and avoiding the drag force (C_D).

3.0 RESULT

The first step in designing the wind turbine blade is the calculation of blade dimension. It is calculated by using various determined variables which are obtained from our implemented wind turbine components [4] and desired turbine outputs. These variables are shown in table.

Table 1: List of determined variables and turbine outputs from implemented wind turbine

Nett Power (P_e)	300 W
Blade Efficiency (C_{PD})	0,35
Transmission Efficiency (η_T)	0,9
Generator Efficiency (η_g)	0,8
Maximum Wind Velocity (V_{max})	7 m/s
Tip Speed Ratio (λ)	3
Blade Number (B)	5
Air Density (ρ_{air})	1,22 kg/m^3

These variables are inputed to various theoretical calculations [2] for obtaining blade dimension. The calculation resulting 1.1 m of blade radius and 0.2 m of hub. It is inappropriate to create a blade design without calculating its geometry. In order to determine it, several aerodynamic calculations [2] and numerical method by software assistance are utilized. The design of blade geometry is basically governed by optimization in wind energy extraction.

$$C_r = \frac{8\pi r}{BC_{PD}}(1 - \cos\phi) \quad (1)$$

In order to obtain a high efficiency and easily manufactured blade, various optimizations are required [5]. Based on our previous research results and literature studies, we use 75% Linearization Optimizations to be applied in our desired design [5], the blade optimizations are divided into two significant steps, i.e. Chord and Twist Optimizations. Chord optimizations are based on appropriate width along each section of the blade to create a design with high capability to extract available wind energy. By using optimization, efficient chords configuration can be obtained.

- 75% Linear Chord Optimization

$$y = -0{,}1243x + 0{,}2902 \quad (2)$$

- 75% Twist Angle Optimization

$$y = -13{,}392x + 23{,}038 \quad (3)$$

Besides chord optimization, twist optimization not only give a significant impact in blades performance and efficiency but also improving its capability to be manufactured resulting in better performance [5].

After the linear equation is known, the equation is used for the geometry linearization process that has been obtained. The result of linerization can be seen in Table.

Table 2: Blade Dimension

Element Radius (m)	*Chord* (m)	Twist Angle (°)
0,20	0,13	20,4
0,31	0,14	18,9
0,42	0,16	17,4
0,53	0,17	15,9
0,64	0,18	14,5
0,75	0,20	13,0
0,86	0,21	11,5
0,97	0,22	10,0
1,08	0,24	8,6
1,19	0,25	7,1
1,30	0,27	5,6

After optimization, geometry can be exported in two dimensions and three dimensions with Autodesk Inventor software.

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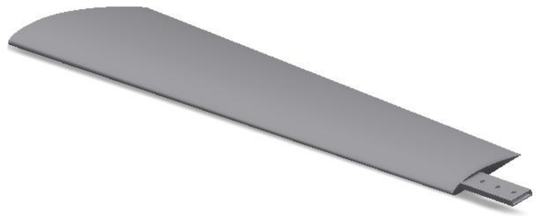

Figure 2: Blade 3D Model

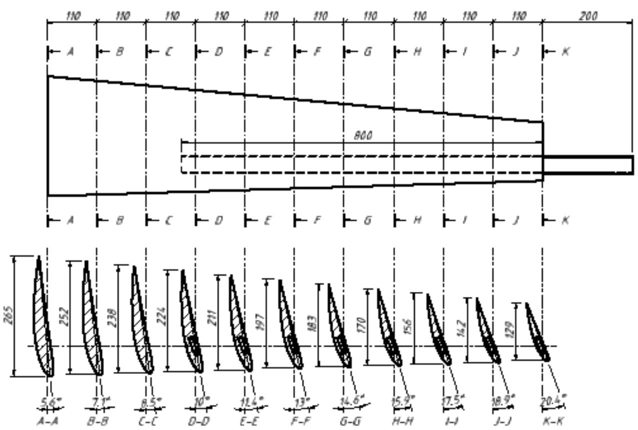

Figure 3: Blade 2D Drawing

After the model is created, the next process is the validation process. The calculated geometry is inputted into the Qblade software to determine the performance of the blade designed.

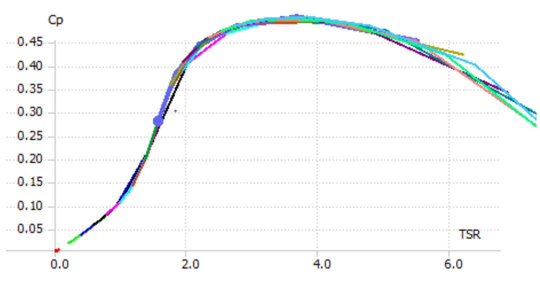

Figure 2 : Cp vs TSR

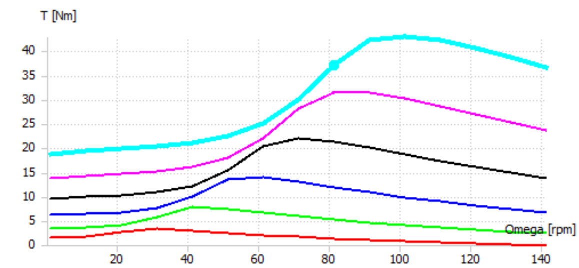

Figure 3 : Torque vs Omega

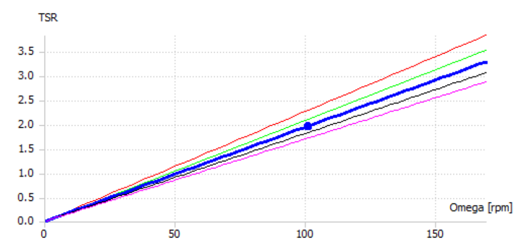

Figure 4 : TSR vs Omega

4.0 DISCUSSION

Cut-In is a phase where the turbine starts to generate power by converting wind energy into electrical energy and produces the minimum electrical power output. This phase can be determined by selecting an appropriate wind speed condition in which its probability value is high enough and the torque generated by rotor exceeds that of required to rotate the coupled transmission and generator system. The calculation and simulation results show that the Cut-In occurs at wind speed of 2 m/s producing mechanical torque (T) of 1.7 Nm, mechanical power (P) of 1.8 watt and rotational speed (Omega) of 10 rpm at TSR and Cp values of 0.68 and 0.068.

The calculation and simulation results show that the optimum condition occurs at wind speed of 5 m/s producing mechanical torque (T) of 16 Nm, mechanical power (P) of 202 watt and rotational speed (Omega) of 121 rpm at TSR and Cp values of 3.29 and 0.5.

Cut-off is a phase in which the turbine stops to generate power by switching off the generator from converting mechanical energy into electrical energy. The purpose of setting the Cut-Off is to prevent the turbine from over speed rotation which subsequently results in overheating. This phase is determined by setting the wind speed condition which probability value is relatively low according to the measured anemometer data. Based on this consideration, the Cut-Off wind speed condition set for this turbine is above 7 m/s

5.0 CONCLUSION

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The results of the design produced blades with a radius 1.1 m and hub 0.2 m and chord length at the base of the blade 0.13 m and at the tip 0.27 m edge chord length with twist angle and tip 20.4^{O} and $5,6^{O}$.

The amount of torque generated results in the speed of rotation of the rotor to be low [7]. So it takes a transmission that can double the rotation and of course doubling the electrical power generated by the generator.

In order to generate electricity, researches and studies of wind turbine generator, controller and battery system are required as further researches for optimization of this technology.

Therefore, a collaboration between various engineers is highly needed for creating sustainable research and study so that the development of wind turbine technology keeps growing rapidly in Indonesia.

The implemented wind turbine can become an alternative source of energy in coastal areas which still sort of electricity for fulfilling daily needs such as seafood processing, public facilities and household daily activities. In order to create an appropriate wind turbine, measurements of wind speed and energy data on local area should be conducted considering that every area has different wind characteristics which subsequently result in different wind turbine design. Therefore, we recommend the Indonesia Ministry of Energy and Mineral Resources to conduct better surveys on and measurements in every potential area so that it facilitates engineers in designing the turbine.

So it can be concluded that the relatively low wind speed in Indonesia can be utilized as an alternative power plant by undertaking new developments in designing wind turbines which are expected to reduce the use of fossil fuels for power generation. One of them is by using blades with inverse taper type.

REFERENCE

1. Y. Nishizawa, "An Experimental Study of the Shape of Rotor for Horizontal Axis Wind Turbine," *Renewable Energy*, vol. 49, pp. 6-9, 2013.
2. T. Burton, Wind Energy Handbook, England: John Wiley & Sons, Ltd, 2001.
3. R. C. Hasting and W. B. R., "Studies of the Flow Field near a NACA 4412 Aerofoil at Nearly Maximum Lift," Royal Aircraft Establishment, Farnborough, England, 1984.
4. Lentera Angin Nusantara, "Pengenalan Teknologi Pemanfaatan Energi Angin," LAN, Tasikmalaya, 2014.
5. F. Gibran and M. Safhire, "Simulation Of Inverse Taper Wind Turbine Blade and Transmission For Indonesia Wind Condition," London, 2015.
6. J. Manwell, Wind Energy Explained, United Kingdom: Jhon Willy & Sons, Ltd, 2002.
7. MIT, Mechanical Engineering, "Designing with D.C. Motors," Center for Innovation in Product Development, 1999. [Online]. Available: http://lancet.mit.edu/motors/index.html. [Accessed 20 Mey 2016].

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