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Comparison of airfoil performance for 120 cm diameter of LLBC-Based Low Speed Wind Turbine

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Abstract. The development of wind turbine attracts more attention as a renewable energy. Layer Laminated Bamboo Composite (LLBC) is a prospective material for rotor blades of low speed wind turbine. Airfoil S834 is commonly used for blade of low speed wind turbine. But there are other airfoils that can be considered, namely S835, S809 and NACA 0012. This research addresses which airfoil shows the best performance for low speed wind turbine. The blade material for wind turbine is LLBC (Laminated Layer Bamboo Composite) which is combination of Gombong Bamboo and Standard Resin. The blade has incidence angle 16^o and twist angle 16^o, respectively. The four blade configurations were compared with the standard blade using ANSYS CFX simulation. The simulation was carried out with 7,9 million elements, frozen rotor as model for interface between static mesh and rotated mesh. The simulations resulted that S834 airfoil showed the best performance as indicated by the highest power generated.

1. Introduction

Indonesia has wind energy potential of 9.2 G with the installed capacity about 1.6 MW [1]. Therefore, it is necessary to develop wind turbines in Indonesia to realize its potential. According to IEC (International Electrotechnical Commissions), wind speeds in Indonesia are categorized to low-medium speed ranging from 3 to 8 m/s [2]. This means low-speed wind turbine is appropriate in Indonesia.

Bamboo is a natural composite that is abundantly available in Indonesia. Bamboo is a potential natural fiber that can be used as an alternative fiber because of high strength to weight ratio [3]. Setiawan et.al. Has tested wind turbines with blades made from Laminated Layer Bamboo Composite (LLBC) material and their performance is still below the turbines on the market with polymer materials [4].

This research is part of the development of LLBC- material based wind turbine designs. One improvement that can be done is by changing the airfoil profile. Based on blade element momentum theory, the airfoil profile strongly influence the performance of wind turbines [5]. Yadav et.al proposed the S834 airfoil to produce the best wind turbine performance and also suggested S835, S809 and NACA0012 airfoil for consideration [6]. However, there is no report on three dimensional analysis when these airfoils are applied to the wind turbine blade. This study aims to evaluate airfoil applied as blade cross section low speed wind turbines with a diameter of 120 cm. The parameter for performance is power which define as torsion times angular speed.

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2. Experiment

The evaluation process is carried out by simulating wind turbines on Computational Fluid Dynamics (CFD) software. The simulation is carried out in a steady state. With the model and boundary conditions as shown in Figure 1.

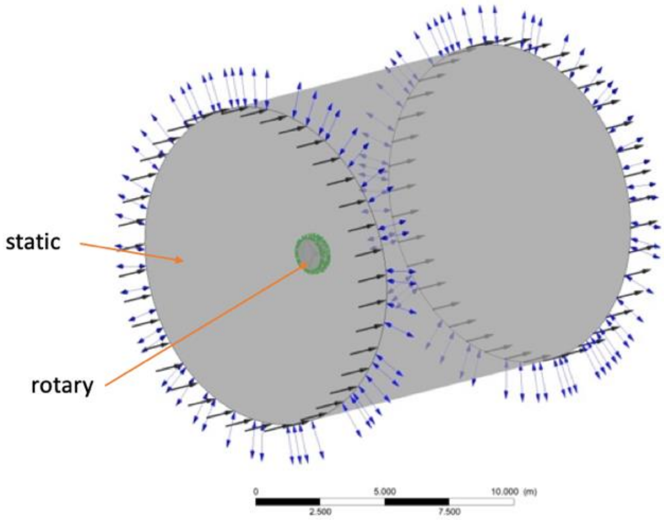

Figure 1. Static and Rotary Region on the CFD Simulation

The model consists of two parts, a static mesh and rotary. The boundary condition between static and rotary mesh is frozen rotor. The boundary conditions that are used at the beginning is the inlet. The side is the opening and the back is the outlet. The turbulence model used in this case is k-epsilon referring to Bouhelal [7]. The detail part of the rotary meshing is shown in Figure 2.

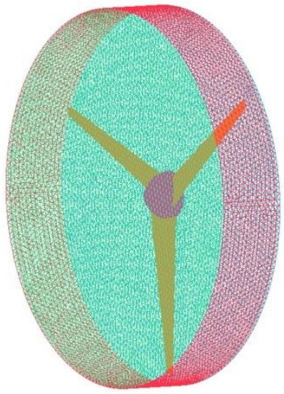

Figure 2. Rotary Region on CFD Simulation

This model has an angle of incidence of 16 degrees and a twist angle of 16 degrees. The total number of elements in this simulation is 7.9 million elements. This model ran in 3 variations of speed namely 5 m/s, 7.5 m/s and 10 m/s. These speeds represent normal wind turbine operating condition.

The simulation is done by rotating the rotary mesh section with an angular velocity of 100 rad/s, based on the results of the wind tunnel experiment conducted by Setiawan etl al. [4]. Analysis of the simulation results was based on the alpha angle read by the airfoil. The Airfoil data were evaluated by the Blade Element Momentum (BEM) Theory explains the lift and drag coefficients to the resulting torque described in equation (1).

$$C_t = C_l sin\phi - C_d cos\phi \quad (1)$$

C_t is tangential force coefficient about turbine rotary plane. C_l and C_d are airfoil lift coefficient and drag coefficient, respectively. The value of ϕ are determined by angular velocity ωof turbine and velocity of freestream V_0, and ϕ is called flow angle. Relation between ω, V_0 and ϕ are expressed by equation (2).

$$tan\phi = \frac{(1-a)V_0}{(1+a')\omega r} \tag{2}$$

Where r is radius of wind turbine, a and a' are velocity induced and angular velocity induced, respectively. Relation between flow angle and angle of attack are conducted by equation (3).

$$\alpha = \phi - \theta \tag{3}$$

Where θ is incidence angle. C_l and C_d are the function of Reynolds number and angle of attack. Equation (1) until (3) are used to evaluate the result of simulation.

3. Results and Discussion

Table 1 provides result of simulation on power generated from various airfoil type and wind speed. In general, airfoil S834 shows the best performance in every condition as indicated by the highest power generation. For speeds of 5 m/s, the S809 airfoil has the second best performance. The second best performance is S809 for 5 m/s, NACA0012 for 7.5 m/s and S835 for 10 m/s wind speeds, respectively. Airfoil S809 and S835 shows unstable power generation at various wind speed.

Table 1. Power generated from various airfoil type and wind speed

No	Airfoil type	Power (watt)		
		v= 5.0 m/s	v = 7.5 m/s	v = 10.0 m/s
1	NACA0012	217.8	326,7	235,9
2	S809	219.8	12,7	unstable
3	S834	247.3	464,8	678,7
4	S835	Unstable	250,7	310,8

The simulation results shown in table 1 are then compared with the results of the blade element momentum theory. The distribution of the tangential force coefficient based on equations (1) to (3) is shown in figure 1. For rotational speeds of 100 rad /s, the area formed by each blade tends to be the same. However, when looking at uniformity, the S834 and S835 airfoil have a uniform distribution. This has an impact on the net rounds produced and the rounds that occur, the more uniform the resulting round will be relatively higher.

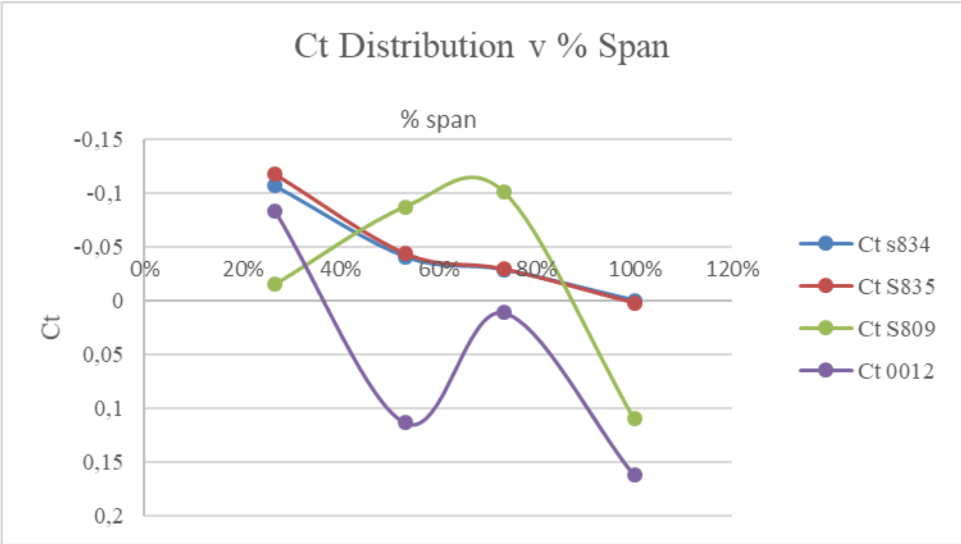

Figure 3. Comparison Distribution of Tangential Force Coefficient using BEM Theory

4. Conclusion

We have successfully compared four type airfoil performance for 120 cm diameter of low speed wind turbine based on CFD simulation. Airfoil S834 provides the best performance for low speed wind turbine applications compared to NACA0012, S834 and S809 airfoils. Power produced by the blade with the S834 airfoil consistently produces the highest power for speeds of 5 m/s, 7.5 m/s and 10 m/s. The airfoil which produces the second best power is different for each speed, S809 for speed of 5 m/s, NACA 0012 for speed of 7.5 m/s and S835 for speed of 10 m/s. The blade element momentum theory shows that the uniformity are happened to airfoil S834 and 835 based blades.

Acknowledgement

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