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Effect fix drag-reducing on blades to performance of savonius wind turbine

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Abstract. This article proposes a design model for vertical axis wind turbines based on drag forces by adding fix drag-reducing to the blades tested by subsonic wind tunnel with wind speeds of 3-6 m/s and opening angle variations of fix drag-reducing from 0, 15, 30 and 45°. The research explained that at the opening angle of 15° can improve the performance of the wind turbine model significantly at high wind speeds on the contrary for larger angle openings. The addition of fix drag-reducing instead reduces the performance of the wind turbine model considerably on all variations of wind speed tested.

1. Introduction

Economic growth and high world population require energy sources, where according to the prediction of the international energy agency [1] in 2030, energy demand increased by 45%, and fossil energy use still dominates up to 80% of the world's energy needs. The use of fossil energy has a severe impact both from the source side where fossil energy is classified as unrenewable energy, as well as the effects of its use on humans related to the environment, where the use of fossil energy causes an increase in carbon emissions which is the main cause of the atmosphere's greenhouse effect which ultimately causes changes climate [2].

Renewable energy is a subject that is highly regarded throughout the world. Wind energy is one of the most promising renewable energy sources, many countries have explored and used wind energy because of pollution-free and the availability of abundant sources of wind energy for conversion where Indonesia according to PEU has wind energy potential of 9 GW with an average wind speed of 3 m/s up to 6.3 m/s [3].

There are two types of vertical axis wind turbines, namely the first type of drug commonly known as Savonius wind turbine, where these turbines work with different drag forces created on the side of the returning blade and advancing blades and the second is the type of lift commonly known as the Darrieus wind turbine, where this turbine works due to the lift force created in the blade [4]. Wind in Indonesia has variable characteristics because Indonesia's geographical position on the equator and its average wind speed are low [5] so that the development of a suitable type of wind turbine is the Savonius vertical axis wind turbine. The performance of Savonius wind turbines is influenced by many things, one of which is the shape of the blade geometry and flow parameters [6].

The influence of the number of blades on the savonius wind turbine has been examined [7-9], the results of their research explain that the number of blades on the savonius wind turbine has an impact on the performance of the turbine and the number of blades two which is the best amount of turbine performance.



Researches related to the geometry of many blades carried out by researchers include Modi and Fernando [10] modifying the blades developed by Savonius, where the new blade was able to increase the value of C_p from the turbine. Kamoji et al. [11] modified the savonius base bar with J-shaped blades in which the returning advancing blades are separated, this modification gets a C_p value of 0.2 while Kacprzak [12] modifies the blades developed by Kamoji by reducing the flat plane of the geometric blades the resulting C_p value is better than the bar developed by Kamoji et al. [11], and Tartuferi [13] develops a new blade for wind turbines based on drag forces named SR 3345 and SR 5050, but the resulting C_p value is no better than the blade developed by kamoji however, the maximum C_p value is achieved at a lower tip speed ratio. Hasan [14] proposed the design of the addition of elliptical fin to savonius turbine blades, the results of which showed the design of savonius wind turbine blades with elliptical fin one capable of producing optimum performance coefficient 0,34 at TSR 0,8.

2. Methods

In the present study, the wind turbine model is made of plate and tested in an open wind tunnel with an exit cross-section area of 2025 cm² with blower specifications diameter blade 16" integrated with speed inverter can produce wind speed range 0 to 15 m/s. The set up of wind turbine models in the wind tunnel can be seen in Figure 1. The model specifications are listed in Table 1 with the sketches shown in Figure 2.

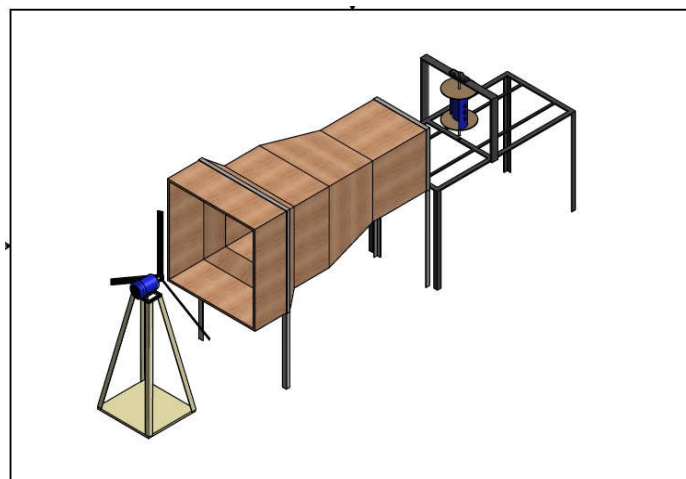


Figure 1. Scheme set up of instruments and test equipment.

Table 1. Wind turbine test model specifications.

Parameters	Form/Value
Blades Geometry	C
Number	2
Arch length, [mm]	140
Rotor Diameter, [mm]	300
Height, [mm]	300
Shaft Diameter, [mm]	15
Number of fix drag-reducing	3 per blade
Dimensions of fix drag-reducing [mm ²]	50 x 50
Top disk material	Arcliryc
Bottom disk material	Arcliryc
Blade material	Plated

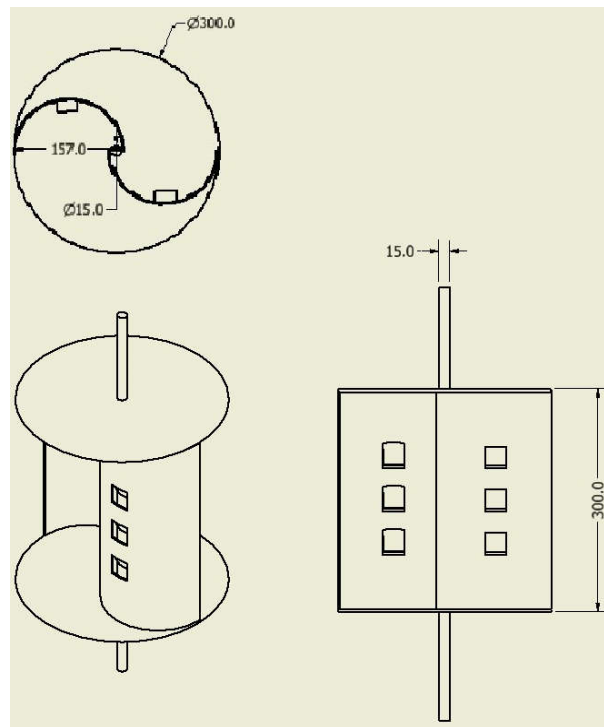


Figure 2. Schematic diagram of the savonius wind turbine.

For the test, the parameter is a large opening of the fix drag-reducing installed on the blades with angle openings of 0° , 15° , 30° , and 45° with wind speeds of 3 to 6 m/s according to the average wind speed conditions in Indonesia. The performance of wind turbines described in a dimension parameter in the form of power density and three non-dimensional parameters in the form of tip speed ratio, power coefficient, and torque coefficient. Power density is defined by the results of measurements of torque and angular velocity (ω) divided by the sweep of turbine A, such as the following equation

$$\text{Power Density} = \frac{T\omega}{A} \quad (1)$$

The tip speed ratio is defined based on angular velocity (ω) measurements, turbine shaft radius (R) and velocity of wind (V_w) like the following equation

$$\lambda = \frac{\omega R}{V_w} \quad (2)$$

While the torque measurement T is used to calculate the power coefficient

$$C_p = \frac{T\omega}{0.5 \rho A V_w^3} \quad (3)$$

For the torque coefficient defined as

$$C_T = \frac{T}{0.5 \rho A R V_w^2} = \frac{C_p}{\lambda} \quad (4)$$

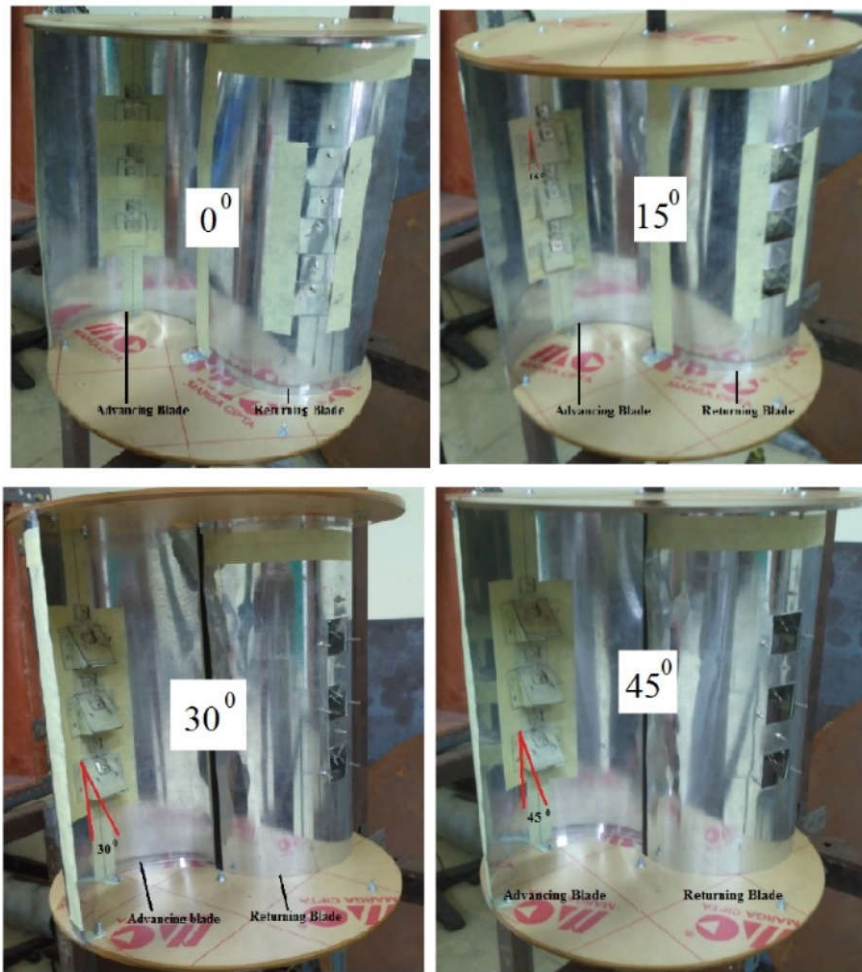


Figure 3. Angle openings of fix drag-reducing.

3. Result and Discussion

In the present study, the wind turbine model is made of plate and tested in an open wind tunnel with exit Performance parameters of the vertical axis wind turbine model with fix drag-reducing (FDR) in the blades with various angle openings (Figure 3) described in the form of power density graphs and performance coefficients of wind turbine test models (C_p) with multiple variations of wind speed can be seen in Figure 4 and 5.

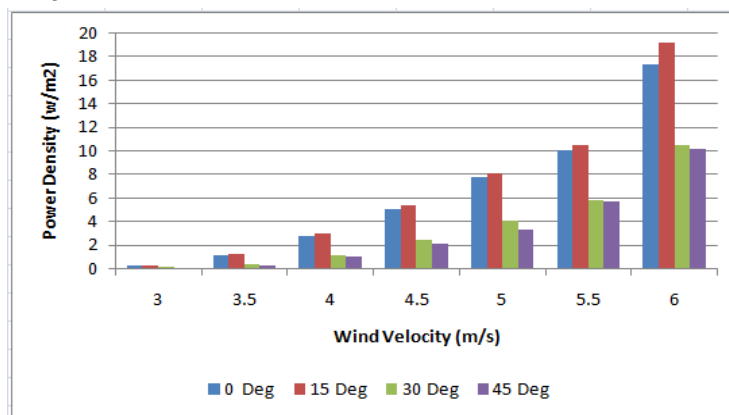


Figure 4. Variations in power density to wind speed.

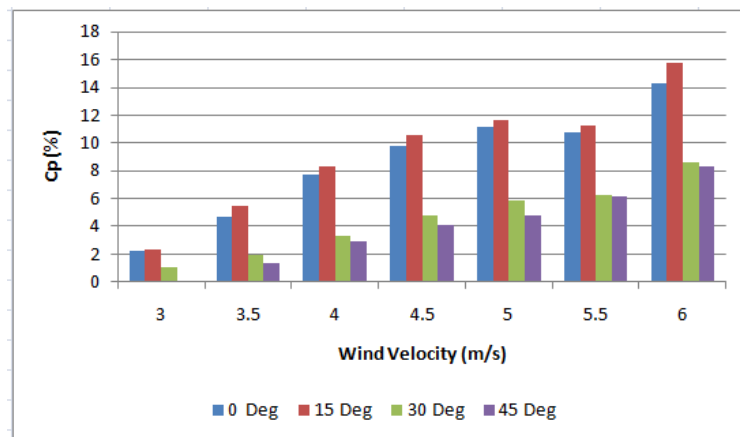


Figure 5. Variation of C_p to wind velocity.

From Figures 4 and 5, the performance of the wind turbine test model that is given fix drag-reducing on the returning blade can increase the performance of the wind turbine test model at a small opening angle precisely at the angle of 15°. The small-angle opening of fix drag-reducing presumes this can reduce drag on the returning blade, but other than that the thrust force expected on the advancing blade side is diminished because there is a slight gap generated at the position of the angle 15°, so that the overall addition of fix drag-reducing on the blade does not add the resulting torque shown in Figure 6 torque produced at an angle of 15° and 0° is not significant enough, but at an angled opening of 15° produces a jet effect behind the blade so that it helps push the returning blade in the direction of the wind in the advancing blade so that overall it can increase the rotation of the wind turbine test model see Figure 7. The effect of this jet is also significant at high wind speeds, so the impact is visible clearly at high wind speeds see Figure 7.

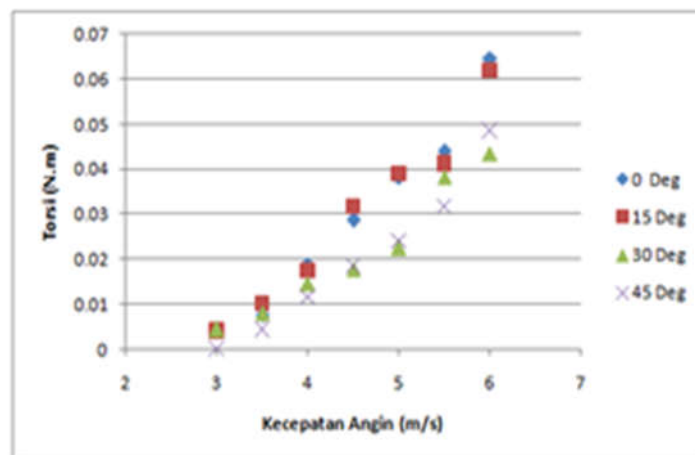


Figure 6. The torque of the wind turbine model for wind speed.

Otherwise increase of the angle of fix drag-reducing in addition to reducing the drag on the side of the returning blade also reduces the thrust on the advancing blade side. This is because the gap on the side gets more significant as the angle of opening increases so that the resulting thrust force decreases, whereas the overall rise of the fix drag-reducing angle results in the performance of the wind turbine test model decreasing can be seen in Figure 4 and 5 in all variations of speed tested.

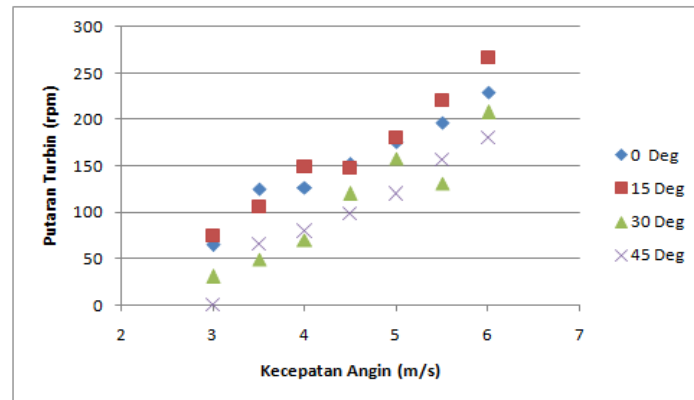


Figure 7. Variation of wind turbine model rotation to wind speed.

Also, the C_p distribution data and torque coefficient of the wind turbine (C_t) test model for the tip speed ratio (λ) are presented in Figures 8 and 9.

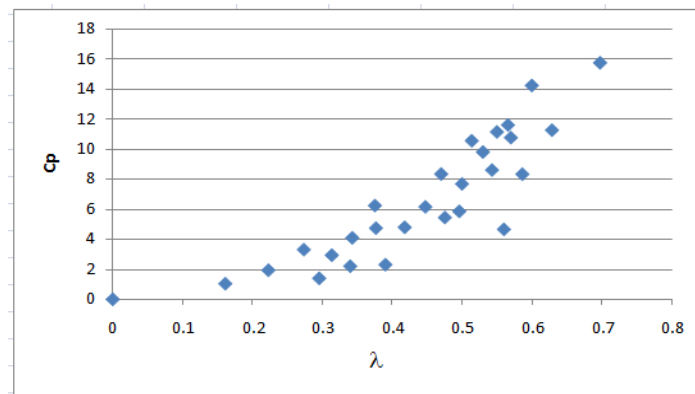


Figure 8. Variation of C_p to tip speed ratio.

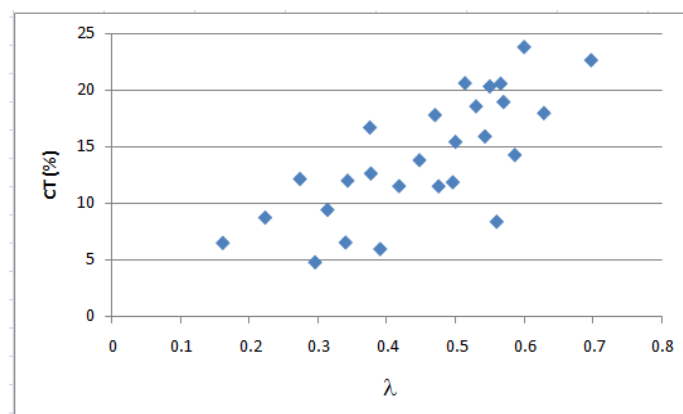


Figure 9. Variation of C_t to tip speed ratio.

There is an interesting phenomenon from the design of the blades under study, where the design of the drag forces-based blades is able to produce larger torque as speed increases can be seen in Figure 9. Besides that, the performance of the wind turbine test model continues to increase as the wind speed increases. There is room for further research related to the wind speed range tested and the opening angle of fix drag-reducing.

4. Conclusions

Fix drag-reducing additions can improve the performance of the wind turbine test model on small-angle openings that is 15° . Otherwise, as the angle opening of fix drag-reducing increases, the performance of the wind turbine test model decreases. Then the addition of fix drag-reducing causes a phenomenon where the torque coefficient (C_t) increases with increasing *tip speed ratio* (λ).

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