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by Indra Siregar

Experimental Investigation of Double Layer Blades as Obstacle Blades on Savonius Wind Turbine Performance

Indra Herlamba Siregar[1], Moch Effendy[1], and Akhmad Hafizh Ainur Rasyid[1]
[1] *Department of Mechanical Engineering*
State University of Surabaya
indrasiregar@unesa.ac.id

Abstract— **Utilization of wind energy potential in Indonesia is still small due to the range of wind characteristics in Indonesia frequently changing direction change and its average speed is also categorized low. For that we need to develop high-efficiency wind turbines at low wind speeds. In this research, a Savonius turbine model was developed as the main blade with 2 obstacle blades, the model was tested in a subsonic wind tunnel at wind speeds of 3-6 m / s with variations in the gap of the main and obstacle blades are 2, 4 and 6 cm. The results explained that at a gap of 6 cm, the presence of an obstacle blade can improve the performance of Savonius wind turbine models by 77.74% at a tip speed ratio of 0.88. In addition, the presence of obstacles can increase the ability of wind turbines to do self-starting.**

Keywords— ***distance gap, double layer blades quarter, obstacle blades, performance, self-starting***

I. Introduction

International energy agency [1] in 2030 explained that energy needs to be increased by 45%, and fossil energy use still dominated up to 80% of the world's energy needs. Besides fossil energy including *unrenewable energy* so that it has serious impacts both from the source and the impact of its use on humans related to the environment, where the use of fossil energy causes increased carbon emissions which are the main cause of the greenhouse effect in the atmosphere which ultimately causes climate change [2]

Renewable energy is a subject of great concern throughout the world. Wind energy is one of the most promising renewable energy sources, many countries have explored and used wind energy because it is pollution-free and the availability of abundant sources of wind energy for conversion where Indonesia according to the Potential Energy Unit (PEU) has a potential wind energy of 9 GW with an average wind velocity of 3 m/sec up to 6.3 m/sec, [3].

There are two types of vertical axis wind turbines, namely the first type of drag, commonly known as Savonius wind turbine, where the turbine works with a difference in drag force created on the *returning blade and advancing blade,* and the second is the type of lift commonly known as Darrieus wind turbine. Where this turbine works due to the lift force created in the blade [4].

Wind characteristics in Indonesia are changing because Indonesia's geographical position on the equator and its average wind velocity are low [5] so that the development of a suitable type of wind turbine is the Savonius vertical axis wind turbine.

Research related to the development of Savonius wind turbines has been carried out where the performance of the Savonius wind turbine is influenced by many things, one of which is the geometry of the blades and the flow parameters [6].

Research related to the geometry of the blades was carried out by researchers such as Modi and Fernando [7] modifying the blades developed by Savonius, where the new blades were able to increase Coefficient of performance (Cp) value of the turbine. Kamoji et al. [8] modified the base blade of Savonius with a letter-shaped blade J where returning advancing blades were separated, this modification received a Cp value of 0.2 while Kacprzak [9] modified the blades developed by Kamoji by reducing the flat plane of the geometric blades the resulting Cp value is better than the blades developed by Kamoji et al. [8] and Tartuferi [10] develop new blades for drag forces based wind turbines called SR3345 and SR 5050, but the resulting Cp value is no better than the kamoji developed blade however the maximum Cp value is achieved on tip *speed ratio* a lower.

In addition to modifying the geometric shape of the blades in an effort to improve the performance of the savonius wind turbine, the researchers also conducted research related to controlling the flow in upstream with augmentation techniques such as the nozzle [11] V-shaped deflector [12], plate-shaped deflector [13], *curtain* [14], slot ventilation [15] guide vane [16] and others, as well as controlling the flow on the surface of the blade by adding plate on the surface of the blade in the form of elliptical fin [17] and adding multiple quarter blades [18].

Research is now focusing on the effect of double layer quarter blades gap on the main blade in an effort to improve the performance of the savonius wind turbine in the wind tunnel.

II. Research Method

In the present study, the wind turbine model is made of PVC and tested in an open wind tunnel with exit cross section area of 2025 cm^2 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 Fig 1.

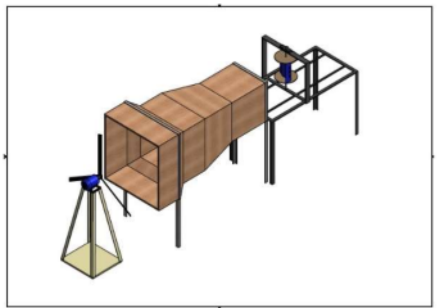

Fig 1. Scheme set up of instruments and test equipment

Measurement of wind velocity with a flexible anemometer with a reading error of ± 0.01 m/s, while the turbine rotor rotation is measured with a non-contact tachometer with an accuracy of 0.01 rpm. For torque measured by the Prony brake method [8], the scheme can be seen in Figure 2.

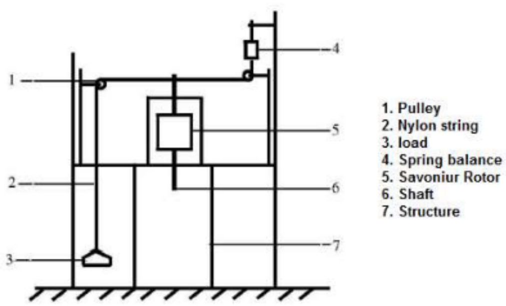

Fig 2. Prony brake scheme for torque measurement

For the test, parameters are the gap of the obstacle blades with the main blades of 2 cm, 4 cm and 6 cm with the savonius wind turbine without interfering as a benchmark defined as a gap distance of 0 cm while the gap between the obstacle blades remains 1 cm. While the tested wind velocity is 3 to 6 m/s according to the average wind velocity conditions in Indonesia.

For the performance of wind turbines described in 1 dimension parameter in the form of power density and 3 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

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

The tip speed ratio is defined based on angular velocity measurements ω, turbine shaft radius R and velocity of wind Vw 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

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

The savonius wind turbine model tested can be seen in Fig 3 with detailed specifications described in table 1.

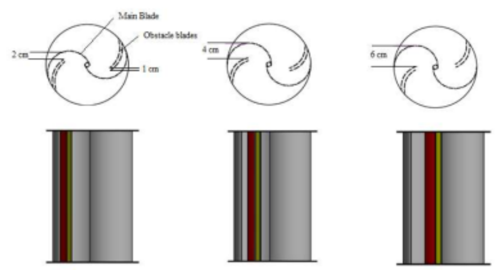

Fig 3. The savonius wind turbine model tested

TABLE 1. Specifications for wind turbine model tested

Parameters	Geometric shape/value
Profile of main blades	C
Number	2
Chord length, [cm]	17
Rotor diameter, [cm]	35
High, [cm]	35
Material	PVC
Profile of obstacle blades	C
Number	4
Chord length, [cm]	7
Material	PVC
Shaft diameter, [cm]	1,5
Material	PE
Top disk material	PVC
Bottom disk material	PVC

III. Results and Discussion

The performance parameters of the vertical axis wind turbine model with an obstacle blade in the form of double layer quarter blades are described in the form of a power density graph and the power coefficient of the wind turbine test model (Cp) can be seen in Fig 4 and Fig 5.

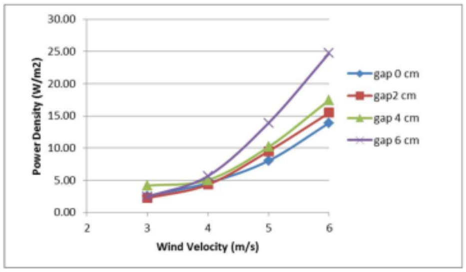

Fig 4. Variation in Power density against wind velocity

Figure 4 shows that the gap between the obstacle blades in the form of double layer quarter blades to the main blade is greater, the incoming flow can be accelerated so as to increase the thrust force in returning blade [18] especially at high wind velocity so that this is thought to cause distance This wide gap at high speed is able to convert wind power into turbine power that is better than a narrow gap distance.

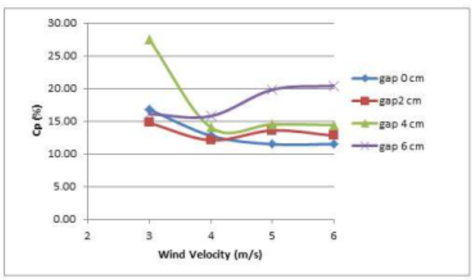

Fig 5. Cp variation in wind velocity

Figure 5 shows the gap below 6 cm the power coefficient of the wind turbine decreases with increasing wind velocity and tends to be constant at wind velocity more than or equal to 5 m/s. Conversely, in a 6 cm gap the wind turbine power coefficient increases with increasing wind velocity and tends to be constant at wind velocity more than or equal to 5 m/s. The highest increase in the power coefficient (Cp) of 77.74% occurs at a wind velocity of 6 m/s see Table 2.

TABLE 2. Effect of gap distance on power coefficient (Cp)

Wind Velocity (m/s)	Increasing Cp (%)		
	Gap 2 cm	Gap 4cm	Gap 6 cm
3	-12.25	63.81	-4.23
4	-5.38	10.08	23.50
5	18.46	26.59	72.90
6	11.25	25.45	77.74

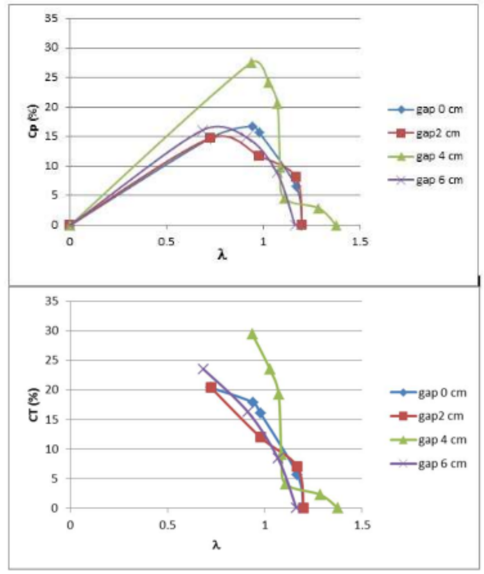

Fig 6. Effect of gap distance on power coefficient (Cp) and torque (CT) at 3 m./s wind velocity

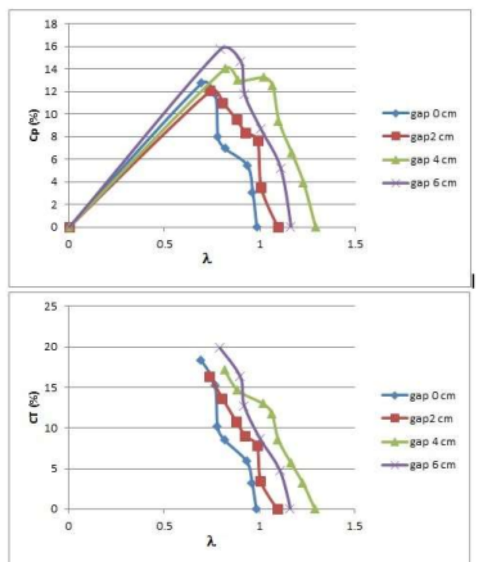

Fig 7. Effect of gap distance on power coefficient (Cp) and torque (CT) at 4 m./s wind velocity

In addition, the distribution data of Cp and the torque coefficient of the wind turbine test (CT) model on the tip speed ratio (λ) are presented in Fig 6 to Fig 9.

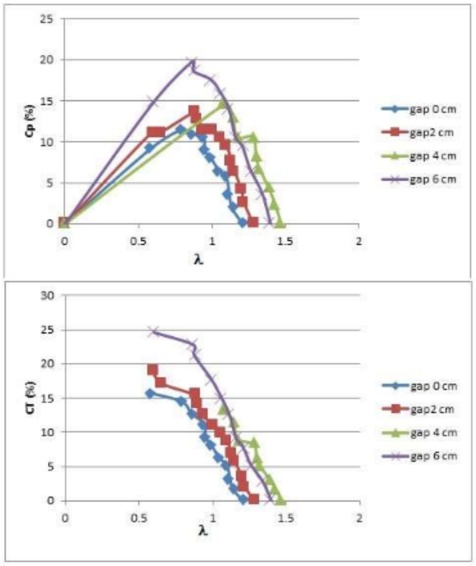

Fig 8. Effect of gap distance on power coefficient (Cp) and torque (CT) at 5 m./s wind velocity

As increase wind velocity, the wide gap distance can accelerate the flow of incoming wind so as to increase the positive thrust force on the returning blade this is also indicated by the increase in torque value as the gap increases, see Fig 6 to Fig 8.

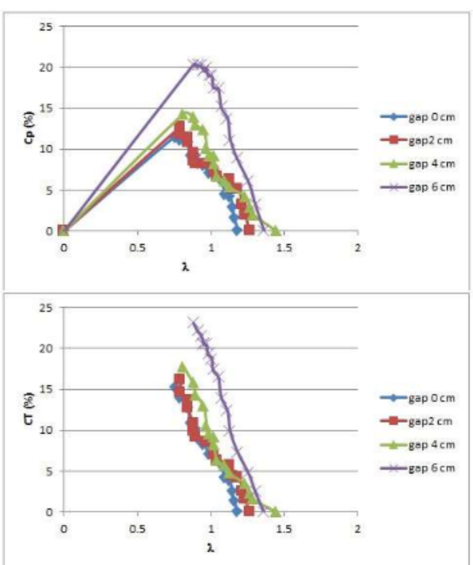

Fig 9. Effect of gap distance on power coefficient (Cp) and torque (CT) at 6 m./s wind velocity

The addition of the obstacle blades in front of the main blade can increase the self-starting of the turbine. It is marked on all wind velocity tested that there is a tip speed ratio greater than one ($\lambda > 1$) wherein this condition the flow in the blade accelerates and a transition occurs the main force that drives the turbine from the drag force to the lift force [19,20].

The performance of the wind turbine model developed by researchers when compared to existing models under the same conditions can be seen in table 3.

TABLE 3. Comparison of Cp models developed with models developed by previous researchers

Parameter	Model Sekarang	Sebelumnya	% Difference
Wind Velocity 6 m/s	0,2	0,07 (Saha et al. [21])	185,7 %
		0,03 (Mahmoud et al. [22])	566,7 %
Tip speed Ratio (λ)=0,8	0,1575	0,18 (Kamoji et al. [8])	-12,5%
Tip speed Ratio (λ)=0,6	0,1482	0,11 (Utomo et al. [23])	34,7 %

IV. Conclusion

Addition of double layer quarter blades in front of the main blade as an obstacle blade can improve the performance of the savonius wind turbine, especially at a gap of 6 cm. Besides that, it can also increase the self-starting ability of the Savonius wind turbine which is indicated by the tip speed ratio value greater than one ($\lambda > 1$)

Acknowledgment

The author would like to thank The Minister of Research, Technology and Higher Education who funded this research through the Universitas Negeri Surabaya, Basic Research Scheme which supported morally and administratively so that this research went well.

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