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Fahrudin, Dominicus Danardono Dwi Prija Tjahjana and Budi Santoso

Experimental Study of Separator Effect and Shift Angle on Crossflow Wind Turbine Performance

Fahrudin[1, a)], Dominicus Danardono Dwi Prija Tjahjana[2, b)], Budi Santoso[3, b)]

[1] *Graduate School of Mechanical Enginering, Faculty of Engineering, Sebelas Maret University, Surakarta 57126, Indonesia*
[2,3] *Mechanical Engineering Departemen, Faculty of Engineering, Sebelas Maret University, Surakarta 57126, Indonesia*

[a)]Corresponding author: fahrudin@student.uns.ac.id
[b)]danar1405@gmail.com

Abstract. This paper present experimental test results of separator and shift angle influence on Crossflow vertical axis wind turbine. Modification by using a separator and shift angle is expected to improve the thrust on the blade so as to improve the efficiency. The design of the wind turbine is tested at different wind speeds. There are 2 variations of crossflow turbine design which will be analyzed using an experimental test scheme that is, 3 stage crossflow and 2 stage crossflow with the shift angle. Maximum power coefficient obtained as Cpmax = 0.13 at wind speed 4.05 m/s for 1 separator and Cpmax = 0.12 for 12° shear angle of wind speed 4.05 m/s. In this study, power characteristics of the crossflow rotor with separator and shift angle have been tested. The experimental data was collected by variation of 2 separator and shift angle 0°, 6°, 12° and wind speed 3.01 – 4.85 m/s.

INTRODUCTION

Electricity is very important for human beings, such as industrial activities, commercial activities, and for daily life. Furthermore, for lighting and fabrication process, including electronic equipment and also industrial machine. Electricity has advantages, especially from conventional resources. Fossil fuels are limited, so there is exploit inexpensive and environmentally friendly renewable energy [2]. One of a kind of renewable energy for long life is wind, wind extracted by the wind turbine [8].

Generally, wind turbine dispute by two, vertical axis wind turbine and horizontal axis wind turbine [6]. Vertical axis wind turbine able accepted wind streamlines from all directions, fast starting and has simple constructions so make it easy to maintain. Nevertheless, vertical axis wind turbine can generate energy 50% from efficiency horizontal axis wind turbine [9].

Vertical axis wind turbine type crossflow transform kinetic energy to be electrical energy used by the generator. Crossflow turbine allows low streamlines velocity, so making high torque sufficiency. Most applications of crossflow turbine on hydropower turbine like impulse turbine [5].

Experimental vertical axis wind turbine with overlap ratio and shift angle differentiation give a value Cp increment significantly from the multistage wind turbine. Multistage wind turbine show best overlap ratio value on the first rotation [6]. End plate capable to give optimized pressure so that can generate blade and improve wind turbine performance [10]. Variation with applying separator on crossflow wind turbine inspired by end plate. The outputs used separator can pressure increase streamline gain on the crossflow wind turbine.

Investigation about crossflow turbine as wind turbine hard to find it. So, need more investigation about the effect the separator, shift angle, and wind velocity of the crossflow vertical axis wind turbine performance. This research, using real condition for predicting performance wind turbine. Variants are wind velocity, separator, shift angel and number of bad [3] [6].

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ENERGY IN THE WIND

For the flow of air flowing through area A, the mass flow rate is ρAV, then the equation expressing kinetic energy through cross section A in each time unit can be expressed as the power through cross section A is as follows :

$$P = \frac{1}{2}\rho A v^3 \quad (1)$$

Where ρ is the air density (kg/m3), V is the wind speed (m/s) and P is the power (watt). The power is also known as the energy flux or power density of the air [4] [8]. The ratio of shaft power (Ps) to the power available in the wind (P) is known as the power coefficient (Cp), and this indicates the efficiency of conversion. Thus

$$C_P = \frac{P_S}{P} \quad (2)$$

In the present investigation, A is the projected area of rotor (m^2), and V is the air speed (m/s) at the tunnel exit. The shaft power (*Ps*) is calculated from brake torque and rational speed (RPM).

CROSSFLOW DESIGN AND FABRICATION

Crossflow turbine or commonly called Bankie water turbine is one of a water turbine. Crossflow turbines can be applied as wind turbines. Crossflow turbine performance is very good and can be an alternative energy for low wind speed areas [3]. The fabrication process of crossflow wind turbines is easier than other wind turbine, because the crossflow turbine has a very simple design [1]. Figure 1. Show the crossflow rotor scheme. This rotor is constituted bay blade and end plate characterized bay the height was H = 400 mm the outer diameter D = 400 mm. With this, the radial rim with a = 140 and the inner diameter D = 260 mm resulted, and the inner/outer diameter ratio was D Out / D in = 1.54. The blades are circular arcs with the radius Rb = 60 mm. The aperture of shift angle is = 18 °. Shaft diameter is 12 mm. The number of blades z = 20 blades. The material used is aluminum with a thickness of 0.5 mm.

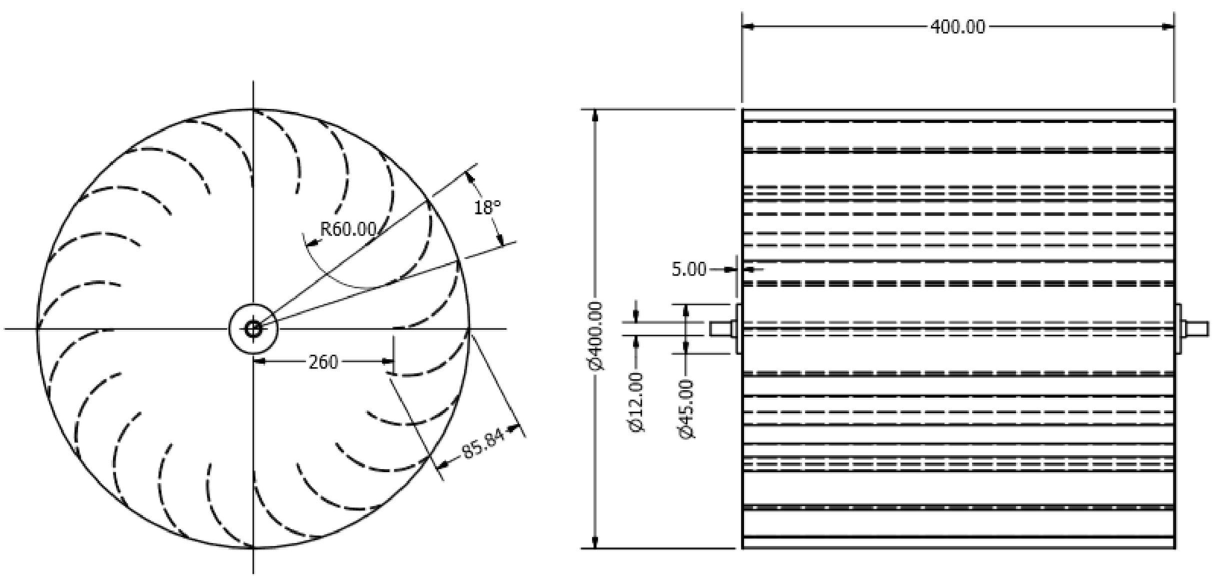

FIGURE 1. Schematic of the crossflow rotor

SEPARATOR, SHIFT ANGLE DESIGN AND FABRICATION

Variations using separators are inspired from using end plates in savonius wind turbines. Application of upper and lower end plates increase the significant value power coefficient 36% then without end plate. Cap increases linearly proportional to end plate area [10]. Spacing between the blades, give affects for the power coefficient to rotate the blades and improve the performance of the wind turbine, it can increase the value was achieved (Kumbernuss et al., 2012). The separator placement is expected to focus the pressure on the blade. In Figure 2. Shows the phase shift angle position 18 ° where the half-rotor crossflow condition 200 mm is given a separator. When rotor in 200 mm, rotor will shift in range, from 0 °, 6 ° and 12 °. This shift is performed to determine the effect of phase shift angle to the TSR of the rotor. Coefficient power vertical axis wind turbines determined by major factors, such as number of blades, shape of blades, overlap ratio and shift angle. Overlap ratio and shift angle is one of the most decisive things because the measured data shows that the cap goes up or down significantly. The rotor is made of aluminum sheet material with a thickness of 0.5 mm. Work is done by using a laser cutting machine, the end plate of the rotor in the weld so that the condition is solid. The solid models for all the three different separator systems are shown in Figure 3.

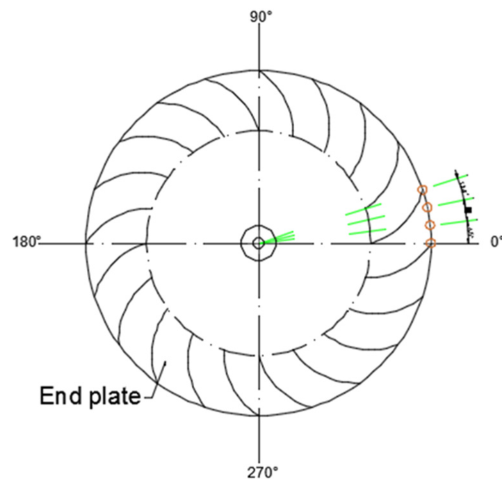

FIGURE 2. Crossflow with 18° phase shift

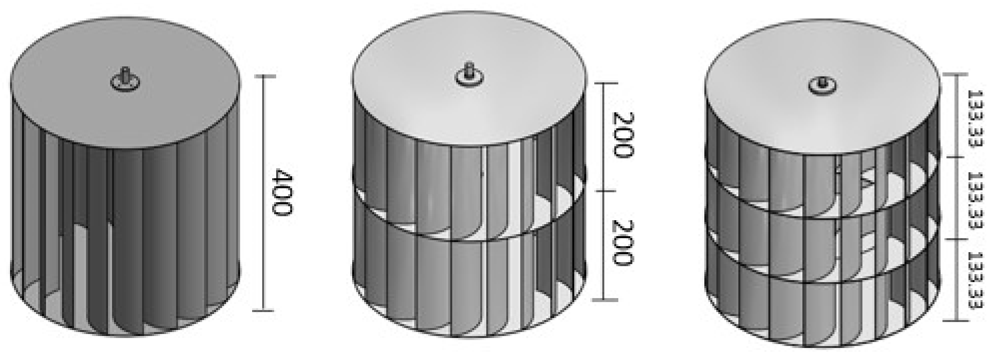

FIGURE 3. Solid models of withot separator, single separator and double sparator rotor system

EXPERIMENTAL SETUP AND PROCEDURE

Figure 4 shows an experimental schematic of the crossflow wind turbine. To study the performance of crossflow wind turbines, settings, wind tunnel in low speed and external tested. Wind tunnel consists of a fan as a wind generator straight line on the rotor, inlet nozzle have a square shape with dimension 500 x 1500 mm, and velocity of 3-6 m / s.

In outlet of the nozzle in addition used ram wire as a wind breaker so wind can be uniformly distributed. Airflow velocity is measured with a digital anemometer at 9 dots set in front of the crossflow rotor. Frequency variable control of the fan is adjusted by using a dimmer so that incoming voltage can be made slow and fast. To measure speed of rotation (RPM) used Tachometrer. Generators are used to convert kinetic energy from the turbines into electrical energy. Generator used a type of permanent magnet generator (PMG) DC that has a maximum power capacity of 100 watts.

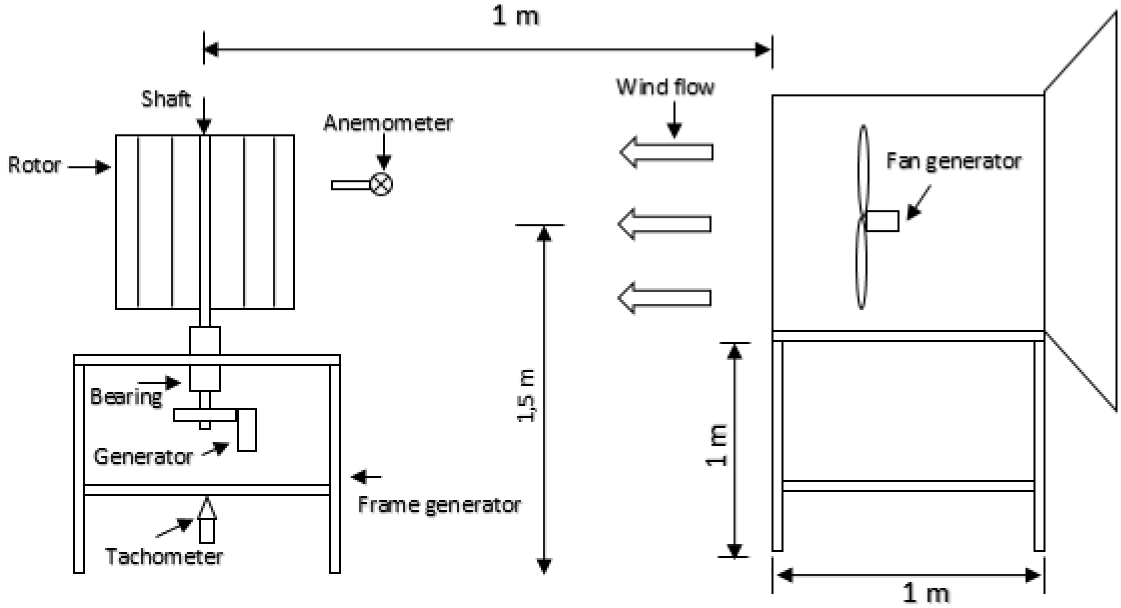

FIGURE 4. Experimental schematic of crossflow wind turbine

RESULT AND DISCUSSIONS

Crossflow rotor performance depends on different parameters such as variables using separator and shift angle. The best way to optimize crossflow rotor performance is by testing in a wind tunnel with different wind speeds. Here, crossflow rotor testing has been performed with varying uses separator and shift angle.

Effect of separator

The experiment result performance without separator is shown together found the effect of separating to crossfow wind turbine shows in figure 5. Figure 5 shows the relationship between cop and wind speed. The value Cpmax crossflow wind turbine without separator is 0.11. Cpmax using by 1 separator is 0.13 and Cpmax by using 2 separator is 0.12. Based on the results, using 1 separator increase Cpmax = 0.13 and the same figure obtained without using separator and two separators.

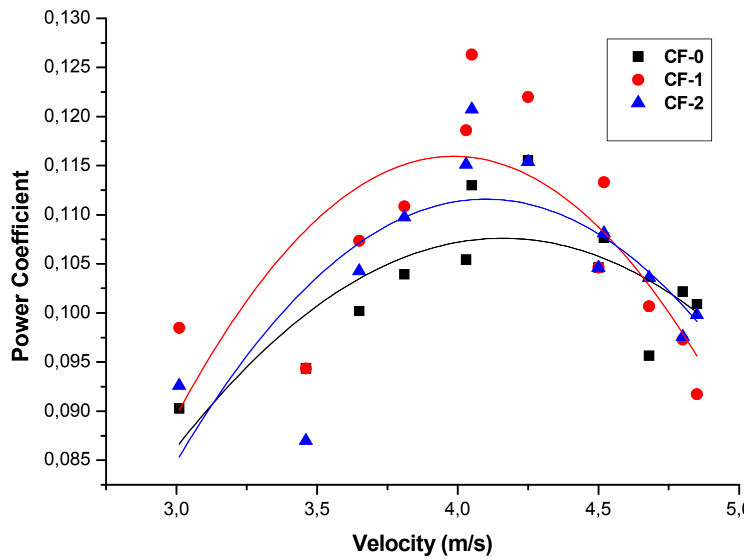

FIGURE 5. Variation of power coefficient with velocity for separator crossflow rotor system

Effect of phase shift angle

The experiment result, no shift angle shown in figure 6, It finds the effect of a shift angle shift in the crossflow rotor. Figure 6. Shows the relationship between cop and wind speed. Cross flow wind turbine performance with shift angle between the blades Cpmax = 0.11 obtained at 0° and 6° shear angle for 12° Cpmax = 0.12. Based on the results show, shifting between the blades did not give significant results to crossflow cap rotor value.

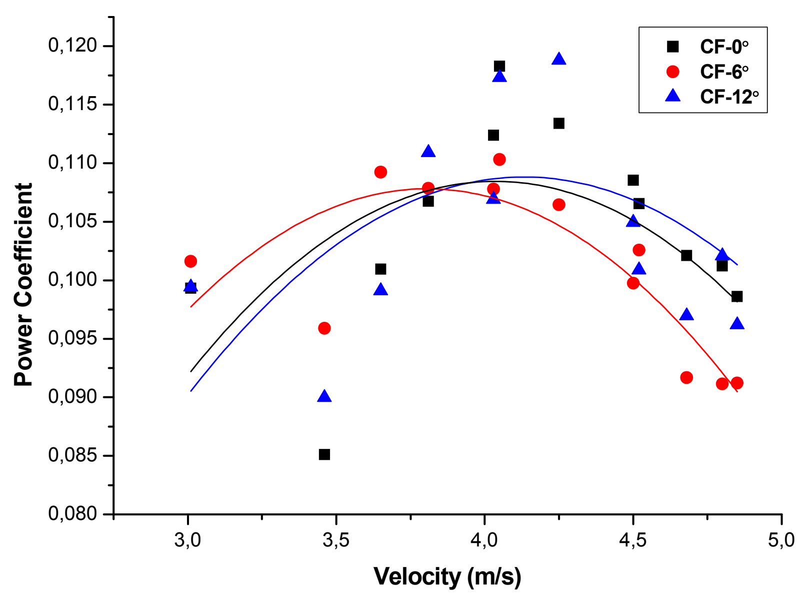

FIGURE 6. Variation of power coefficient with velocity for phase shift angle crossflow rotor system

Variation of RPM with velocity

Basically rotor kept stable, sees like figures 7 and 8, and airflow velocity in the inlet to the rotor increases slowly with the help of divers. The different airflow velocity, RPM rotor measured by digital tachometer. Airflow velocity has a range differs from 3.01 to 4.85 m /s. Pada dasarnya the test system using separator and shift angle has been done. This observed, both RPM and wind velocity increased on the crossflow rotor with one separator shows in Figure 7. Variations with shift angle show in Figure 8. Where the RPM followed wind velocity increasement. Initially airflow velocity is basically still less noticeable, in the image that the RPM continues to rise in either the 7 or 8 images.

RPM using separator and shift angle crossflow has been studied and compared with crossflow rotor type without variation. On the single crossflow rotor separator RPM rises compared with no RPM separator decreases. In a different conditions in the shift angle where all RPM variations increase. In addition, of separator and shift angle, improving performance by reducing the negative torque.

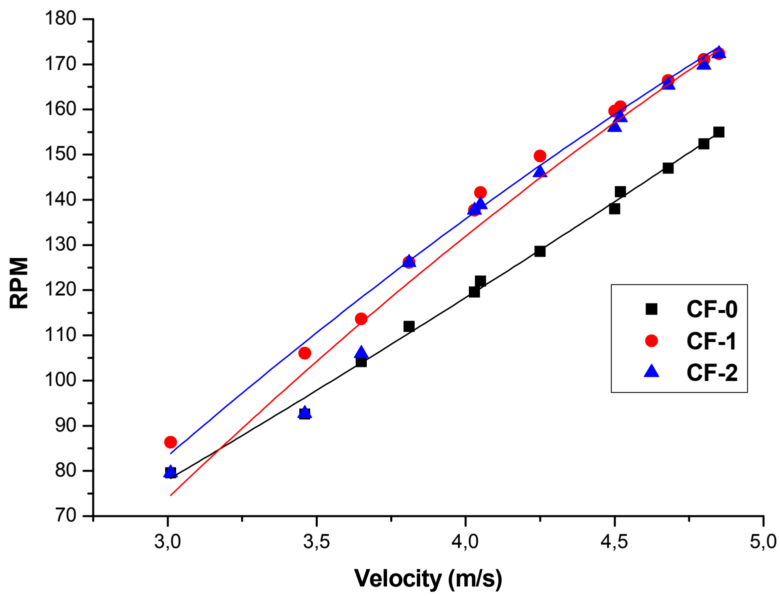

FIGURE 7. Variation of RPM with velocity for separator crossflow rotor system

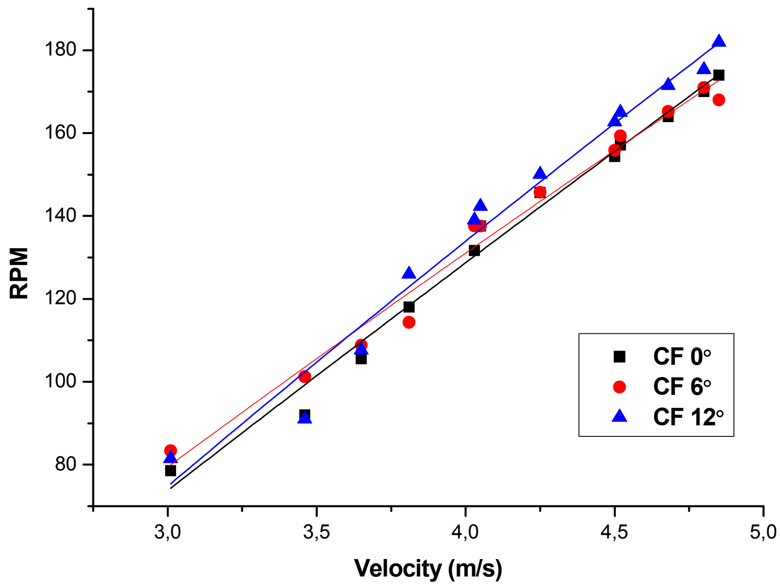

FIGURE 8. Variation of RPM with velocity for phase shift angle crossflow rotor system

CONCLUSION

Based on the experimental data and discussion on the effect of separator and shift angle on vertical crossflow axis wind turbines, the following conclusions can be drawn:

1. Crossflow turbine using one separator is the best turbine with sufficient power 0,13 with wind speed 4.05 m/s.
2. The effect of the best shift angle at 12 ° shift angle position with Cpmax = 0.12 at wind speed 4.05 m/s.
3. Variations of separator and shift angle provide good value, thereby reducing the negative torque.

The maximum efficiency of the variation by using the separator needs to be increased to 20% because the crossflow wind turbine has advantages over low wind speed, good self-starting, and easy maintenance.

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