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Sandi Susanto, Dominicus Danardono Dwi Prija Tjahjana and Budi Santoso

Experimental Tests of The Effect of Rotor Diameter Ratio and Blade Number to The Cross-Flow Wind Turbine Performance

Sandi Susanto[1], Dominicus Danardono Dwi Prija Tjahjana[1,a)] and Budi Santoso[1]

[1]Mechanical Engineering Department, Engineering Faculty, Sebelas Maret University, Surakarta 57126

[a)]Corresponding authors: ddanardono@staff.uns.ac.id

Abstract. Cross-flow wind turbine is one of the alternative energy harvester for low wind speeds area. Several factors that influence the power coefficient of cross-flow wind turbine are the diameter ratio of blades and the number of blades. The aim of this study is to find out the influence of the number of blades and the diameter ratio on the performance of cross-flow wind turbine and to find out the best configuration between number of blades and diameter ratio of the turbine. The experimental test were conducted under several variation including diameter ratio between outer and inner diameter of the turbine and number of blades. The variation of turbine diameter ratio between inner and outer diameter consisted of 0.58, 0.63, 0.68 and 0.73 while the variations of the number of blades used was 16, 20 and 24. The experimental test were conducted under certain wind speed which are 3m/s until 4 m/s. The result showed that the configurations between 0.68 diameter ratio and 20 blade numbers is the best configurations that has power coefficient of 0.049 and moment coefficient of 0.185.

INTRODUCTION

The reduced supply of fossil fuels and limited other natural resources are the common issues in Java Island. Wind energy is one of an option as an alternative energy source [1]. Wind energy is one potential source of energy for the regions in Indonesia, but not utilized properly. The utilization of wind energy is by moving a converter to change the kinetic energy of the wind which later can be utilized as a generator drive, water pump etc. In this case, the wind turbine energy converter is the blades.

In this research, wind turbine using micro scale modeling that shown on Fig 1. The material of cross-flow wind turbine is aluminium

FIGURE 1. Cross-flow wind turbine

The type of wind turbine which is tested is turbine with cross-flow type. This turbine has several advantages, which is capable of produce high torque and lower dependence on wind direction [2]. Another advantages from this turbine is capable to rotating in low wind velocity. Those advantages make this turbine suitable to apply on a rural in

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Indonesia. Cross-flow turbine is a turbine with vertical axis direction, then this turbine has a simple construction and easy in the manufacturing and maintenance process [3]. To get a good cross-flow turbine performance, the authors determine the parameters that effect on performance of turbine.

To get the best cross-flow turbine performance, the authors determine the parameters that affect this turbine. Power coefficient is one of the important parameters for determining wind turbine performance. The parameters are influenced by several things such as the number of blades and rotor diameter ratio. Those parameter are variation in this experiment. The increase in rotor diameter ratio causes the energy transfer distance from level 1 to level 2 to be closer, it will affect the value of turbine efficiency [4]. In addition, variations in the number of blades can increase turbine efficiency up to 12.93% [5]

These parameters are very influential on cross-flow turbine performance. So in this research, writer will make cross-flow turbine with variation of turbine blades amount and rotor diameter ratio. This study aims to determine the effect of the number of blades and the ratio diameter of blade to the cross-flow turbine power coefficient. Utilization of cross-flow turbine as wind turbine is still rarely encountered because it has some limitations, it is necessary to do further research to determine the performance of cross-flow turbine as wind turbine

EXPERIMENTAL METHOD

Cross-flow Wind Turbine Model

Experimental of this cross-flow wind turbine modeling is based on the results from Pradityasari research. In her research, the cross-flow wind turbine are modeled with ANSYS-CFX to determine the coefficient power of the turbine. In this experiment, this cross-flow wind turbine is designed using inventor software. This cross-flow wind turbine made with a laser cutting machine to obtain high precision results. Precision manufacturing results will make the test results more accurate

The cross-flow wind turbine specifications as shown in Table 1

TABLE 1. Cross-flow wind turbine specification

Specification	Value
Blade radius	54 mm
Angle of wind entry	30º
Outer diameter, D_o	400 mm
Blade height	400 mm
Thickness	2 mm
Material	Aluminium

The example of cross-flow wind turbine design is shown on Fig 2.

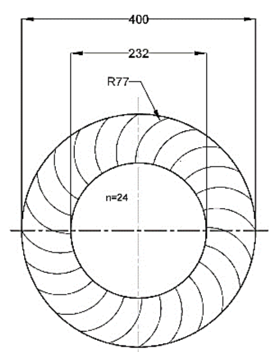

FIGURE 2. Cross-flow wind turbine model

In this study proposed cross-flow turbine with variation of the blade number and the rotor diameter ratio. The rotor diameter is comparison between inner diameter turbine and outer diameter turbine. The rotor all variations will be tested with wind speed variations from wind generator. The variations conducted in this study are as follows

TABLE 2. Variation of cross-flow wind turbine

Rotor diameter ratio	Blade number
0.58	16
0.63	20
0.68	24
0.73	

The first trail is to test the rotor diameter ratio variation. After obtaining the best results of the rotor diameter ratio variation, the next test is the blade number variation by taking the best rotor diameter ratio. This method generate the best configuration of the combination between rotor diameter ratio variations with the number of blades variations. For the first testing of rotor diameter ratio, the amount of the blade uses 20 blades

Experiment Set Up

Wind Generators

Wind generator used consists of two industrial fan with the following specifications:

- Fan diameter: 26 inch
- Power: 187 watts
- Voltage fan motor: 220 volts

The wind generators is shown on Fig 3.

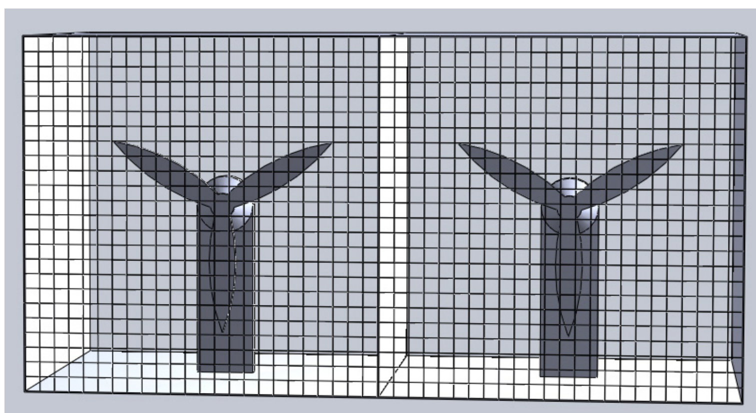

FIGURE 3. Wind Generators

In this experiment, the wind generators are set to 3 parts of voltage to be the benchmark of wind variations. The fan voltage setting is using the multimeter tool to ensure the fan output voltage is always same every variation. The voltage settings are 135, 155, 170 and 205 watts. The wind velocity generated by each of the voltages is 3.43; 3.59; 3.99; 4.24 m/s.

In this experiment, the equipment is set up as shown in the Fig 4. The wind source in the experiment use two wind generators to produce high wind. The mesh applied In front of wind generator to make the wind more uniform.

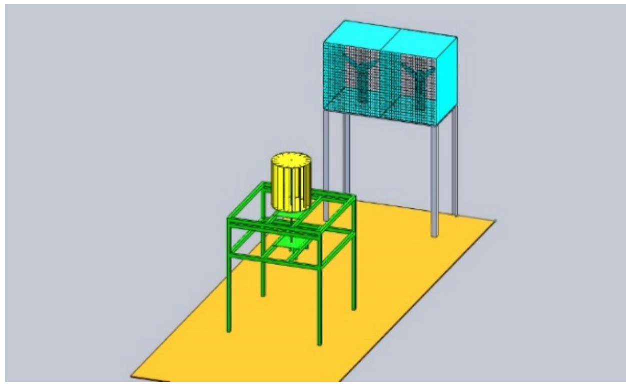

FIGURE 4. Experiment set up

There is distance between wind generators and cross-flow wind turbine to get a uniform wind. The distance between wind generators and cross-flow wind turbine is 1.5 meters. This distance is obtained from trial and error until it gets a uniform wind speed. Wind speed is measured using vanes anemometer

The rotation of the turbine is measured by laser tachometer. Torque measurements on the turbine are carried out under the turbine by prony brake system. Prony brake system use scales and loads to measure torque. Scales and loads connected by a 5mm diameter rope. On the prony brake system, turbine is allowed to spin from a no-load condition, and then loaded gradually by adding 50g of mass for ten times. Prony brake system shown in Fig 5.

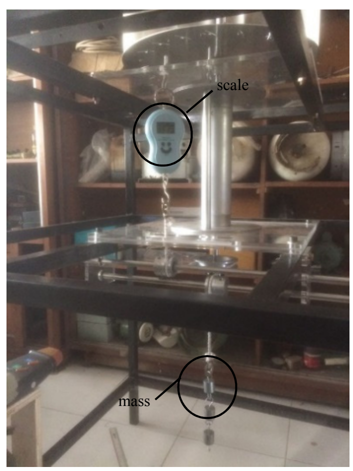

FIGURE 5. Prony brake system

RESULTS AND DISCUSSION

The datas in this research are wind speed in turbine (m/s), turbine spinning rotation (rpm), mass read by hand digital scales on prony brake system (kg). The datas used to obtain wind power (watt), power on the shaft generated by turbine (watt), tip speed ratio and coefficient power from turbine cross-flow

Wind Speed Data

Wind velocity is measured using vanes anemometer. Wind velocity changes is regulated by controlling the voltage of the wind generator using a multimeter. Voltage used is 135, 155, 170 and 205 volts. The wind velocity data is shown on table 3

TABLE 3. Data of wind velocity

V1	V2	V3	V4
3.43 m/s	3.59 m/s	3.99 m/s	4.24 m/s

These wind velocity variations are used to test the performance of each turbine variation in rotor diameter ratio and the blade number

Data Of Cross-Flow Wind Turbine Performance In Rotor Diameter Ratio Data

The test was conducted with variation of diameter ratio of 0.58, 0.63, 0.68, 0.73. The wind speed is adjusted to the regulated wind generator voltage. This test result two graphs, coefficient moment graph and coefficient power graph. Cross-flow wind turbine performance can be seen in the graph of the relationship between coefficient moment and TSR below.

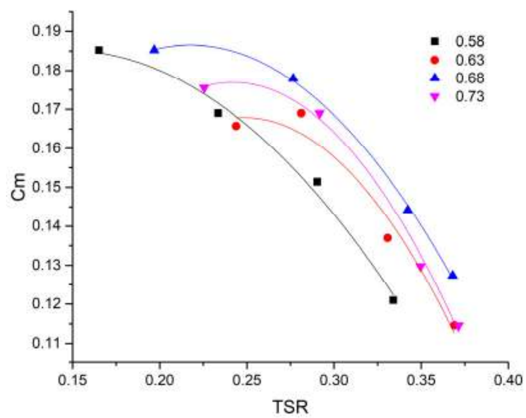

FIGURE 6. Graph relation between Cm vs TSR

The graph shows the value of the coefficient moment which tends to decrease along with the increase of tip speed ratio. The highest coefficient moment was achieved by a turbine with a 0.68 rotor diameter ratio at TSR 0.165 which is 0.18. At the lowest TSR value of any variation rotor diameter ratio, the value of the coefficient moment for the diameter ratios of 0.58, 0.63 and 0.73 are 0.175, 0.166 and 0.175 respectively. Cross-flow wind turbine performance can be determined from the coefficient power (Cp) generated by cross-flow wind turbines.Cp value is shown on Fig 7.

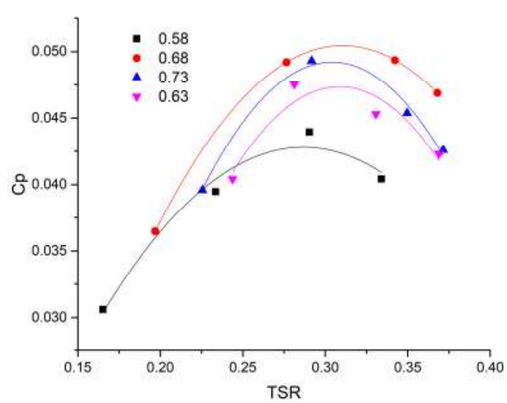

FIGURE 7. Graph relation between Cp vs TSR

On Figure 7, The 0.68 rotor diameter ratio has a higher coefficient power value compared to the 0.58, 0.63 dan 0.73 rotor diameter ratio. Highest coefficient power value that is equal to 0.0493 which is achieved in turbine with diameter ratio of 0.68. The power coefficient values in the diameter ratios of 0.58, 0.63, 0.73 are 0.044, 0.047, 0.049 respectively.

The value of the diameter ratio will affect the magnitude of the radial rim value. The magnitude of the radial rim is the difference between the outer diameter and the inner diameter divided by two or (D1-D2) / 2. A radial rim that is too large will cause the amount of wind to hit the turbine blade unable to flow through a cross section that is too small and will cause back or negative pressure, while the width of the rim is too small will cause the transfer of energy that will be greater and will increase turbulence causing decreased power coefficient

Data of cross-flow wind turbine performance in blade number variation

The test was conducted with variation blade number 16, 20 and 24. The blade number variation use the rotor diameter ratio 0.68 which is the best result from the previous test. This test result two graphs, coefficient moment graph and coefficient power graph. Graph relation between Cm vs TSR is shown on Fig 8.

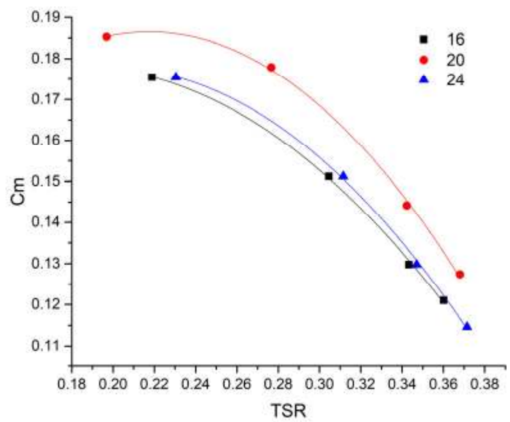

FIGURE 8. Graph relation between Cm vs TSR

The graph shows the value of the coefficient of moment which tends to decrease along with the increase of tip speed ratio. The highest coefficient of moment was achieved by a turbine with a 20 blade number at TSR 0.21 which is 0.18. at the lowest TSR value of any variation blade number, the value of coefficient moment for the blade number of 16 and 20 are 0.175. Coefficient power (Cp) result from balde number variation is shown on Fig 9.

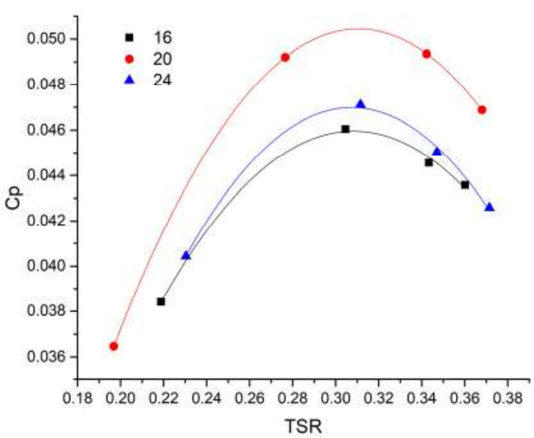

FIGURE 9. Graph relation between Cp vs TSR

On Figure 9, The number of blades 20 has a higher coefficient power value compared to the 16 dan 20 blades number. Highest coefficient power value that is equal to 0.0493 which is achieved in turbine with 20 blade number. The power coefficient values in the number of blades 16 and 24 are 0.046, 0.047. The number of high blades will create tighty gap between blades, while the number of blades that are too small will result in greater losses so that its resistance will decrease [6].

The results obtained have similar trends with previous simulation studies, but the value is still much smaller when compared with previous studies. This happened due to several unfulfilled factors during this experiment testing. This several factors are non uniform wind, turbulance wind on the turbine, unperfectly on use of prony brake system. These factors cause the Cp value is very small

CONCLUSIONS

Based on data analysis and discussion about the effect of rotor diameter ratio and blades number, it concluded that turbine with 0.68 rotor diameter ratio and 20 blades number have the best result on turbine performance. The value of coefficient power is 0.0.49 on TSR 0.34, and coefficient moment value is 0.18 on TSR 0.21.

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REFERENCES

1 Daryanto, Y., Balai PPTAAG, Yogyakarta. (2007)
2 Kawamura, T.S., Yuko, Kyoto University Research Information Repository, Vol. 1288: pp. 44-51. (2002)
3 Colley, G., Mishra, R., Rao, H. V., and Woolhead, R, European Association for the Development of Renewable Energies, Environment and Power Quality (2010)
4 Sammartano, V., dkk, Energies, Vol. **6**: pp. 2362-2385 (2010)
5 Acharya, N., Journal of Renewable Energy, Vol. **80**: pp. 819-826. (2015)
6 Hau, E., Springer Berlin Heidelberg, Berlin (2013)