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Diniar Mungil Kurniawati, Dominicus Danardono Dwi Prija Tjahjana and Budi Santoso

Experimental Investigation on Performance of Crossflow Wind Turbine as Effect of Blades Number

Diniar Mungil Kurniawati[1*], Dominicus Danardono Dwi Prija Tjahjana[2], Budi Santoso[3]

[1,2,3]*Mechanical Engineering Department, Faculty of Engineering, Sebelas Maret University, Surakarta 57126, Indonesia*

*Corresponding author: kurniawatidiniar@student.uns.ac.id

Abstract. Urban living is one of the areas with large electrical power consumption that requires a power supply that is more than rural areas. The number of multi-storey buildings such as offices, hotels and several other buildings that caused electricity power consumption in urban living is very high. Therefore, energy alternative is needed to replace the electricity power consumption from government. One of the utilization of renewable energy in accordance with these conditions is the installation of wind turbines. One type of wind turbine that is now widely studied is a crossflow wind turbines. Crossflow wind turbine is one of vertical axis wind turbine which has good self starting at low wind speed condition. Therefore, the turbine design parameter is necessary to know in order to improve turbine performance. One of wind turbine performance parameter is blades number. The main purpose of this research to investigate the effect of blades number on crossflow wind turbine performance. The design of turbine was 0.4 x 0.4 m^2 tested by experimental method with configuration on three kinds of blades number were 8,16 and 20. The turbine investigated at low wind speed on 2 – 5 m/s. The result showed that best performance on 16 blade number.

INTRODUCTION

Wind turbine is one of an alternative energy to decrease electricity load in urban living area. Generally, urban living has many high rise building, so installation wind turbine can be interesting way to decrease electricity load. In urban living also there is a wind velocity problem like a low wind velocity and the turbulence almost occurred [1].

Nowadays, there so many devolopment of multi blades Banki wind turbine as a basic design of crossflow wind turbine. The efficiency of Banki water turbine is high because of the energy produced by two sides of turbine surface area; the first side when the wind entered and push in front of turbine surface, the second when the wind passed the turbine and push the back surface of turbine. Moreover, the influence of the blades number can make the turbine able to have low cut in speed and high starting torque [2].

The Banki wind turbine with 8 blades number investigate by experiment with the 30˚ angle of attack showed the maximum Cp 0.3 and the tip speed ratio relatively high between 0.35 – 0.6 and the wind flow relatively continue around the blades with minimum friction losses [2]. The performance of crossflow wind turbine with 2 – 6 blades number investigate by experimental method in 20 m/s wind speed showed the result that 6 blades gave the best performance [3]. Experimental investigation for 12, 15 and 18 blades number of crossflow wind turbine resulted that the best performance of crossflow wind turbine on 12 blades with the maximum efficiency more than 0.12 [4].

The turbine performance analyze by numerical investigation was executed on 1 x 1 m^2 with 20 blades number crossflow wind turbine. Based on the result, the turbine had maximum Cp 0.45, Ct approached 3.6 and the tip speed ratio less than 0.6 [5]. Three variation of crossflow wind turbin there was 3, 6 and 12 blades number investigated by Computational Fluid dynamic (CFD) simulation. The parameter performance of the wind turbine was Cp, Ct and TSR. The result showed that the maximum power decreased by decreasing the blades number [6].

The number of blades was determined based on the estimation on the opposite direction of the wind flow. The development of variation blades number intended to control better direction of wind flow. The best blades number had the minimum friction force between wind flow and blades [7]. The producing of wind turbines with lots of blades did not have simple construction and geometry, although the turbine performance is essentially better than wind turbines with fewer blades number [2].

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The investigation on the performance of crossflow wind turbine in this research was by using the experimental method. The objective of this research was to know the influence of blades number variation on the performance of crossflow wind turbine. The investigation set on the low wind speed about 3 – 5 m/s. the turbine parameter used 3 models of blades number, there were 8, 16, and 20 size 0.4 x 0.4 m^2.

EXPERIMENTAL METHOD

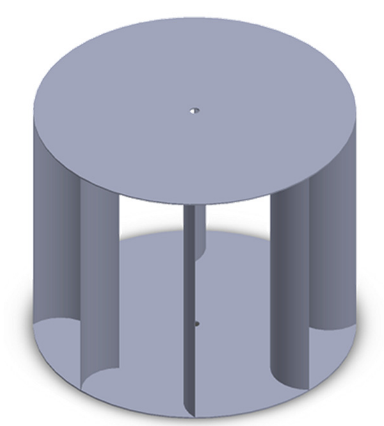
Experimental Schematic

This research emphasizes experimental investigation on the best performance by blades number variation. The design of crossflow wind turbine is small scale wind turbine, it was sized on 0.4 x 0.4 m^2. Blades number which were used in this research are 8, 16 and 20. The blades profile used arc profile. The crossflow turbine specific that used in this research as shown at **Table.1**. Crossflow wind turbine used at tihis experiment shown as **Fig.1**. The turbine aspect ratio is 1 with $_{Do}$ 400 mm and H 400 mm. Material that used to build the turbine is Aluminium with thickness 1.5 mm.

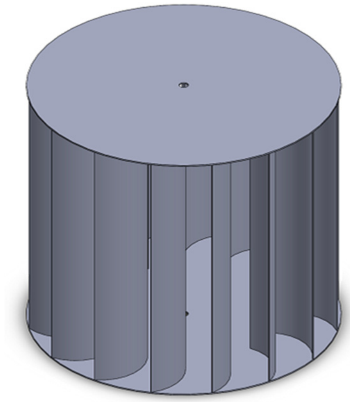
TABLE 1. Crossflow wind turbine specification

Parameter	Value
Outer Diameter (D_o)	400 mm
Inner Diameter (D_i)	240 mm
Turbine Height (H)	400 mm
Aspect Ratio	1
Blades length	60.12 mm
Shaft Diameter	12 mm
Blades Number	8, 16 and 20

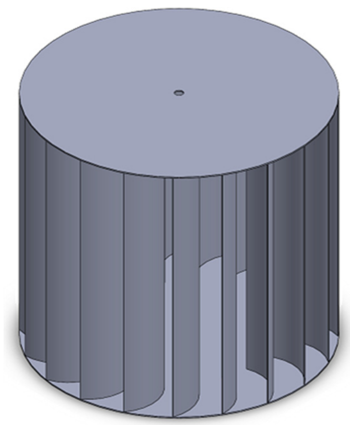
Wind source that used in this research is from fan blower. The fan blower is placed about 0.2 m from the turbine installation. Wind speed that produced by fan blower is measured with anemometer around the turbine in front of the sweep area of fan blower. Wind speed was set on 3 – 5 m/s based on the low wind speed condition. To defend the rotation of turbine shaft, in this research used transmission system by gears. The turbine rotation is measured by tachometer and the output power of turbine measured by permanent magnet generator (PMG). **Fig.2** shows the schematic experimental apparatus of crossflow wind turbine testing.



1(a). 8 blades model



1(b). 16 blades model



1(c). 20 blades model

FIGURE 1. Model of crossflow wind turbine

Procedure of The Experiment

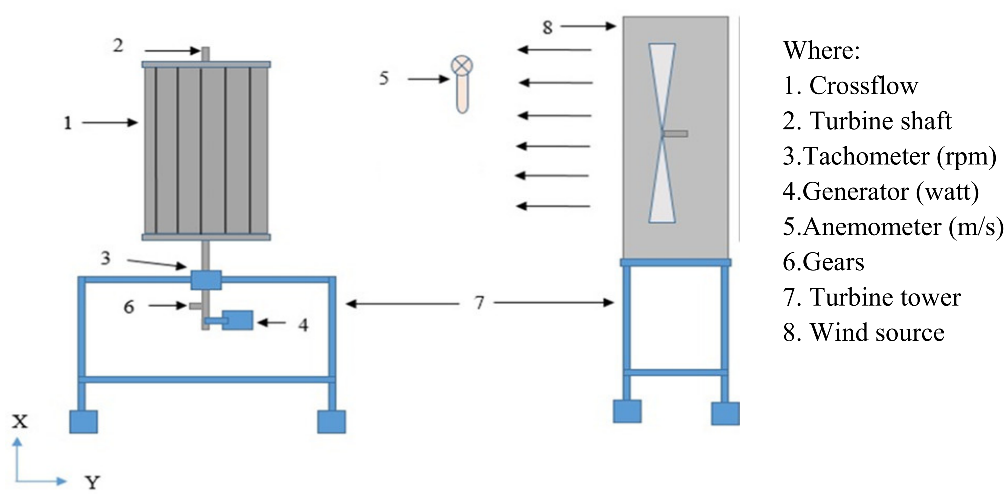


FIGURE 2. Schematic experimental apparatus of crossflow turbine testing

Wind Turbine Theoretical Performance

Available energy on wind is a kinetic energy from most of motion air mass on earth surface. The blades turbine receive kinetic energy then transformed to mechanic energy or electric energy based on the last uses. The wing conversion efficiency to different energy based on the rotor will be interacted with wind flow [8].

The actual power of rotor is choosen as the efficiency where the energy will be transfered to the rotor. Wind turbine efficiency is ussually as a power coefficient (C_P). So that, the C_P of rotor can be definited as the ratio between actual power on available wind flow is :

$$C_P = \frac{2P_T}{\rho_a A_T V^3} \tag{1}$$

Where, Pt is the outcome power of turbine. C_P of turbine depend on some factor like blades profile, baldes formation, blades setting etc.

$$C_T = \frac{2T_T}{\rho_a A_T V^2 R} \tag{2}$$

Where T_T is the atual rotor torque. While, the ratio between C_P and C_T known as tip speed ratio (TSR). TSR also definited as the ratio between tip rotor velocity and wind velocity. So the TSR can be described as :

$$\lambda = \frac{C_P}{C_T} \tag{3}$$

C_P and C_T of the turbine rotor have variation to TSR. Optimum TSR when energy transfer on the maximum efficiency condition and C_P also at the maximum point (C_P max).

RESULT AND DISCUSSION

Experimental Result

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The characteristics of crossflow wind turbine has good self-starting and good starting torque as standard to develop the turbine. Meanwhile, wind turbine is one of environment friendly and zero pollution renewable energy. The developing of crossflow wind turbine in order to electricity generation is being a good study case in wind turbine research. The crossflow wind turbine model was tested by experimental investigation for a variation of wind speed and blades number. Each variation of blades number tested on wind speed variation between 2 – 5 m/s. Turbine tested to get data and analyzed by wind turbine theoretical formulas. Data analyze as a parameter performance of wind turbine such as C_P, C_T and TSR. The testing result are presented in **Table 2**. Based on the result the best output power from the turbine is 2.01 Watt at the 16 blades turbine at 4.85 m/s wind speed. Output power increase by increasing wind speed.

Power coefficient (C_P) of wind turbine is comparison between output power produced by turbine which is measured on generator with theoretical power turbine. C_P of crossflow wind turbine formed parabolic curve that reached maximum value on current TSR then decrease on the next TSR value . So, the increasing C_P based on increasing TSR. Torque coefficient (C_T) showed comparison of measured torque at turbine shaft with theoretical torque of turbine. Different with C_P, C_T produce negative slope curve on increasing TSR. So, decreasing C_T as a function of decreasing TSR.

TABLE 2. Experimental result of crossflow wind turbine

v (m/s)	8 blades				16 blades				20 blades			
	P (W)	C_P	C_T	TSR	P (W)	C_P	C_T	TSR	P(W)	C_P	C_T	TSR
2.84	0.26	0.112	0.259	0.432	0.35	0.153	0.389	0.392	0.17	0.072	0.196	0.369
3.01	0.38	0.140	0.258	0.543	0.46	0.169	0.371	0.457	0.25	0.090	0.173	0.521
3.46	0.58	0.139	0.246	0.565	0.73	0.175	0.358	0.490	0.36	0.087	0.159	0.545
3.65	0.77	0.158	0.248	0.640	0.92	0.189	0.363	0.520	0.51	0.105	0.162	0.644
3.81	0.88	0.159	0.241	0.657	1.06	0.192	0.352	0.545	0.63	0.113	0.168	0.675
4.03	1.01	0.154	0.237	0.648	1.30	0.198	0.358	0.553	0.70	0.108	0.159	0.675
4.05	1.17	0.176	0.245	0.719	1.41	0.212	0.356	0.595	0.73	0.109	0.158	0.692
4.25	1.28	0.167	0.231	0.721	1.60	0.208	0.293	0.712	0.85	0.111	0.157	0.705
4.50	1.42	0.156	0.215	0.723	1.73	0.190	0.262	0.726	0.84	0.093	0.126	0.734
4.52	1.45	0.157	0.210	0.746	1.77	0.192	0.253	0.759	0.92	0.099	0.132	0.754
4.68	1.54	0.150	0.201	0.747	1.95	0.190	0.233	0.817	0.92	0.090	0.119	0.755
4.80	1.57	0.142	0.190	0.749	2.00	0.181	0.210	0.863	1.06	0.096	0.125	0.765
4.85	1.61	0.141	0.184	0.765	2.01	0.176	0.195	0.906	1.07	0.094	0.119	0.785

Figure 3. shows the graph between C_P versus TSR of 3 variation blades of crossflow wind turbine. From the graph, the maximum C_P is 16 blades crossflow wind turbine followed by 8 and 20 blades. $C_{P\ max}$ 0.21 on 4.05 m/s wind speed and 0.59 TSR. The 8 blades turbine produced $C_{P\ max}$ 0.17 on 4.05 m/s wind speed and 0.72 TSR. Meanwhile, 20 blades turbine reached $C_{P\ max}$ 0.11 on 3.81 m/s wind speed and TSR 0.67.

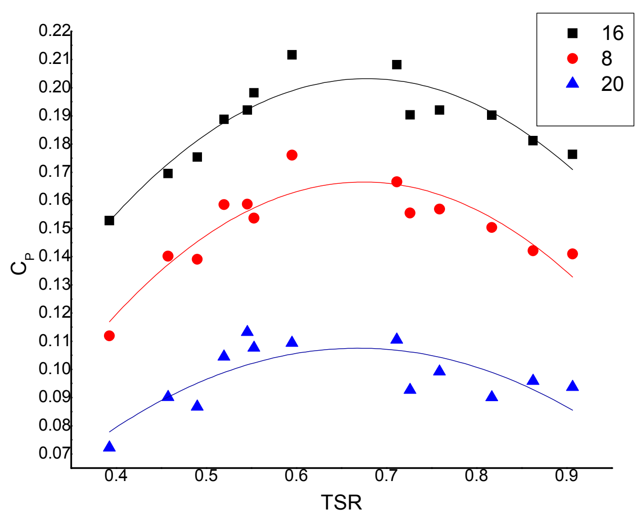

FIGURE 3. Graphic between C_P vs TSR

The torque coefficient with the different variation of blades number is depicted in **Fig.4**. and has been tested in a range of blades tip speed ratio (0.3 – 0.9). It can be seen that the rotor generates the maximum C_T of 0.389 is found on the 16 blades number at TSR 0.392. 8 blades number produced maximum C_T of 0.259 at TSR 0.432 and the 20 blades produced $C_{T\ max}$ of 0.196 0n TSR 0.369.

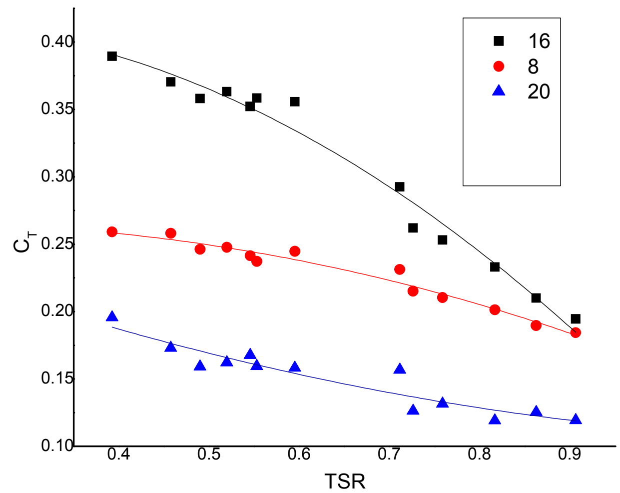

FIGURE 4. Graphic between C_T vs TSR

CONCLUSION

Increasing the number of blades on a crossflow wind turbine can increase Cp until certain blades number. Blades number influence wind flow to direct blades. The best wind turbine is the turbine with 16 blades. The highest Cp is 0.21 at TSR 0.59 and the highest CT is 0.38 at TSR 0.4. Output power of 16 blades crossflow wind turbine is the maximum value than another variation of blades number. Maximum power which is produced by the 16 blades is 2.01 watt. 0.4 x 0.4 m^2 crossflow wind turbine with 16 blades number able to produce the best C_P.

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