Analysis of Effect of Different Parameters on Performance of Vertical Axis Wind Turbine

Rugwed Bhatkande[1], Shray Jerath[2], Malhar Ozarkar[3], Saurabh Chandorkar[4], Atul Kulkarni[5], Abhijeet Deshpande[6]

[1,2,3,4] *Student, Vishwakarma Institute of Information Technology, Pune, India*
[5,6] *Vishwakarma Institute of Information Technology, Pune, India*

Abstract: A wind turbine in which the main rotor shaft is aligned vertically is called a Vertical Axis Wind turbine (VAWT).The advantages of this arrangement are that the turbine does not need to be pointed into the wind to be effective and they can be installed at a lower altitude which improves accessibility for maintenance. VAWTs are mainly categorized as Giromill, Darieus and Savonius turbines. For the present study, a 6-bladed Giromill with NACA0020 blade profile was used to analyze the effect of performance parameters on the rotational speed (RPM) of the turbine. The parameters varied are rotor diameter, attack angle of the blade and wind velocity. The rotor diameter was varied from 0.12 m to 0.2 m, the blade angle from 20° to 30° and the wind velocity in the range of 3.5 m/s to 5 m/s. It was observed that with increase in wind velocity and the attack angle of the blade, the rotational speed of the turbine increased whereas the rotor diameter was inversely proportional to the rotational speed.The co-relations between the rotational speed and the other performance parameters are developed by minimizing the least square error between the experimental and predicted values of rotaional speed obtained in wide range of conditions. The co-realtion coefficient was found out to be close to 0.94, which shows that the model was reliable andcould be used effectively for predicting rotational speed. It was found that the wind velocity is the most influential parameter.

Keywords: Wind Energy, RPM, VAWT, Giromill, Full Factorial Method

1. INTRODUCTION

With the continued rapid development of economy, energy problem in the world has become more and more critical. Together with the need to ensure long term security of clean energy supply, it imposes an obligation on all of us to consider ways of reducing our carbon footprint and sourcing more of our energy from renewable resource. Vertical-axis wind turbine (VAWT) is a wind turbine that has the main rotor shaft arranged vertically. The vertical axis wind turbines have many advantages over horizontal wind turbines such as they can be located near the ground. The generator and the gearbox are placed at ground level. This makes the maintainance of the turbine quite easy.The VAWT is also quite cost effective. They can be placed in any area were the force of the wind is more near the ground. Since they are placed lower, they can be used where tall devices are not allowed by the law. The main advantage of VAWT, however, is that it turns in any direction with the wind; so, they do not need the yaw mechanism that is required in the horizontal axis design. As a result, the use of VAWT may be efficeint; although of having some disadvantages such as, they cannot cover a large area of wind. They are not very efficeint with regards to extraction of energy because they operate near the ground where the air flow is turbulent.

An example of the design of Giromill wind turbine was previously carried out and the analysis of some design parameters was explained by Solum et al. [1]. The designed wind turbine was a three bladed 12 kW H-rotor with tapered NACA 0018 wing sections. Also, the experimental results for this turbine were introduced and studied by Deglaire et al. [2], the turbine performance was investigated and it was found that its performance was satisfactory to these conditions.

The effect of some design parameters such as, pitch angle and airfoil type has been previously introduced with some data for comparision and analysis by M. El-Samanoudy et al. [3]. It was shown by Hwang et al.[4] that by controlling the pitch angle of the blade, a better performance can be achieved.

2. EXPERIMENTAL SETUP

Components. The Vertical Axis Wind Turbine prototype has following components.

1)Shaft: The shaft used is made of stainless steel (SS 314) with diameter of 12 mm and length 285 mm as shown in Fig. 1.

2)Blades: The aerofoil blades used are manufactured according to NACA 0020 specifications. The material used is SS 314 and the blades are manufactured on horizontal Lathe machine using a dedicated fixture for the same. The cord length of the blades is 40 mm and the span length is 220 mm. there are tapped holes on the upper and the lower surfaces of the aerofoil blades. These blades are mounted and fixed to the spoke of the supporting link by bolts. The angle of attack can be varied manually by loosening of the bolts.

3)Spoke shape link: The spoke shape link as shown in Fig. 1 has 6 spokes for mounting the blades. Two such links are used above and below the blades. The material used for these links is stainless steel. The main function of these links are to transmit the power from blades to shaft. There are 3 holes on each spoke at the distance 60 mm, 80 mm and 100 mm from the center of the link. These holes facilitate to change the rotor diameter to 120 mm, 160 mm and 200mm respectively.

4)Bearings:The beaings used are; two deep groove ball bearings(*SKF-6200-2Z/C3*) with inner diameter 10 mm and outer diameter 30 mm. These bearings permit the relative motion between the turbine shaft and the supporting frame. One bearing is placed at the top side of the frame while the other at the bottom side as shown in Fig. 1.

5)Supporting frame: The main function of the supporting frame is to support the turbine assembly. The two bearings are mounted in the frame as shown in Fig. 1 The frame is designed according to the test section of the subsonic wind tunnel. The dimensions of the frame were chosen according to the test section.

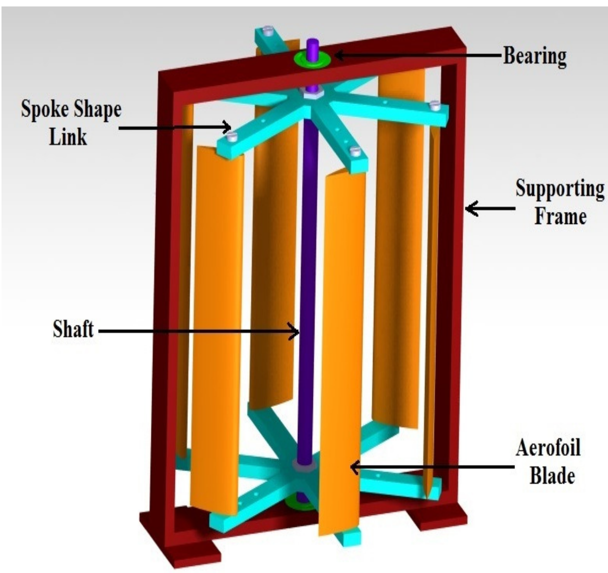

Fig. 1: CAD model **Fig. 2: Actual Experimental Setup**

Instrumentation

1)Tachometer: The tachomter of make LUTRON DT-2235B was used to measure the rotational speed of the turbine with an accuracy of ± 1%

2)Anemometer : The vane anemometer is an instrument used to measure the wind speed. It was mounted in the test section of the wind turbine as shown in the figure. It measured the wind speed with an accuracy of ± 0.5%

Wind Tunnel Setup. A subsonic wind tunnel with a capacity to produce winds from 0.5 m/s to 27m/s was used to simulate the wind conditions required. The wind tunnel is divided into 3 sections viz. Suction side, Test section, and discharge side. As shown if Fig. 3

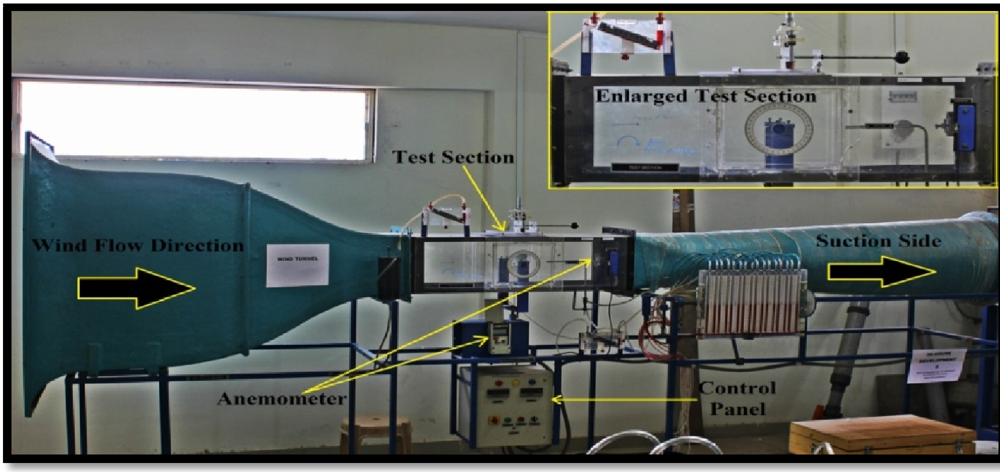

Fig. 3: Wind Tunnel Setup

Process of Experiment Design. To determine the best set of parameters among the effective factors, the full factor method was choosen. Hence the selection of factors that will affect the rotational speed, selection of levels and based on Full factorial method was needed. In accordance to this method, 36 experiments were performed.From the Analyis of Variance (ANOVA) table (Table 1) it can be seen that the *p-value* is less than 0.001 which suggestes that the model and levels selected are significant. The predicted "R-squared" of 0.9343 is in reasonable agreement with the "Adjusted R-squared value" of 0.9503.

Table 1:Analysis of Variance

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F
Model	32832.80028	7	4690.40004	96.69768842	< 0.0001
A-Dia	3823.383889	2	1911.691944	39.41160465	< 0.0001
B-wv	26699.7475	3	8899.915833	183.4814261	< 0.0001
C-blade ang	2309.668889	2	1154.834444	23.80816569	< 0.0001
Residual	1358.162778	28	48.50581349		
Cor Total	34190.96306	35			

3. RESULTS

Effect of Rotor diameter on Rotational speed. The curves shown in Fig. 4 were obtained by changing the rotor diameter from 0.12 m to 0.20 m by keeping the attack angle of the blade constant (25°).We can see that with increase in the rotor diameter, the performance of the turbine decreases significantly.The lower performance at the higher rotor diameter is due the effect of the shaft and downwind blades on the flow past the blades which decreases the velocity of the wind past the blades.

Effect of Wind velocity on Rotarional speed. Fig. 5 explains the effect of increase in wind velocity on the performance of the turbine.These curves were obtained by keeping the angle of attack of the blades constant (20°).The wind velocity was varied in the wind tunnel. Rotor diameter was also varied from 120 mm to 200mm to obtain results for various iterations.

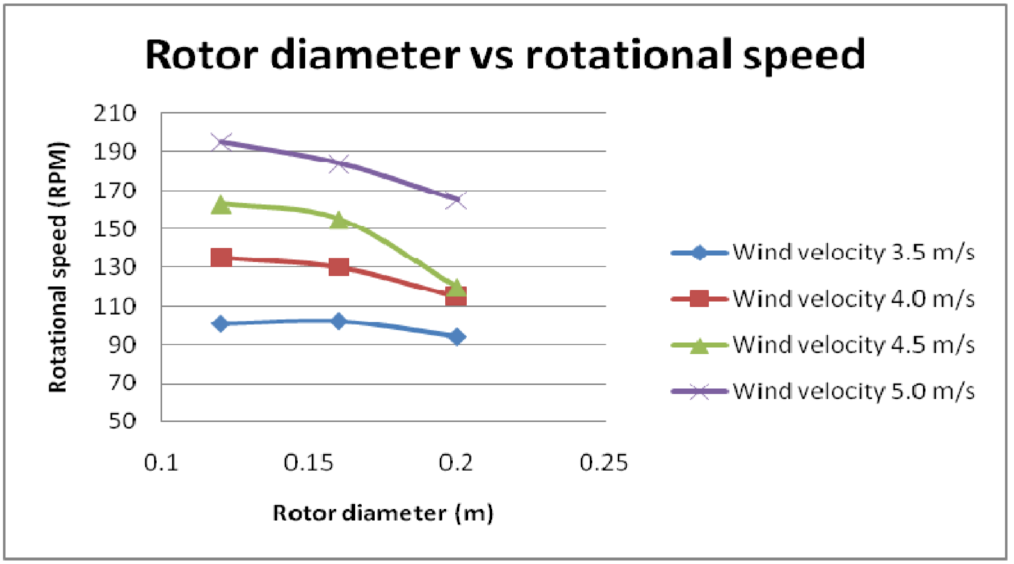

Fig. 4: Graph Portraying Rotor Diameter vs Rotational Speed

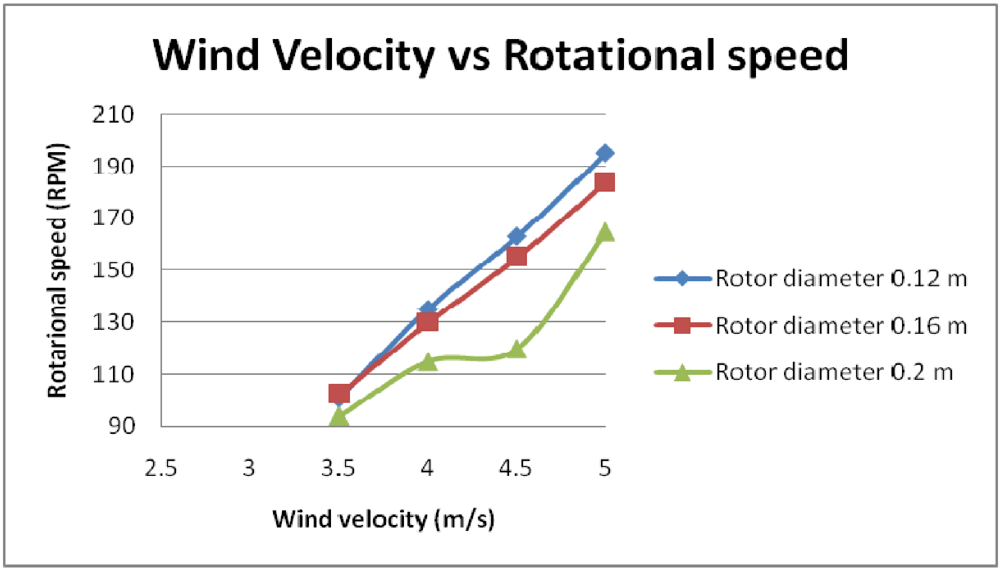

Fig. 5: Graph Portraying Wind velocity vs Rotational Speed

It was observed that with increase in the wind velocity the rotational speed of the turbine increases linearly. The graph of wind velocity against rotational speed has similar charachtersitcs to the graph of a cubical equation which verifies the result.The equation for power obtained from turbine is given by the equation stated below-

Theoritical power obtained from a turbine,

$$P = 0.5*\rho*A*V^3 \quad (1)$$

Effect of attack angle of the blade on rotational speed. Fig. 6 shows the effect of increase in attack angle of the blade above the stall angle for NACA 0040 (11°). To obtain significant difference in the performance of the turbine, the blade angle was varied from 20° to 30° keeping the wind velocity constant at 4 m/s and varying the rotor diameter from 0.12m to 0.2 m.It can be concluded from the graph that the performance of the turbine increases when the attack angle of the blade was increased above its stall angle. As the blade angle increases, the vector of the wind velocity parallel to the chord length of the blade increases, improving the performance of the turbine.

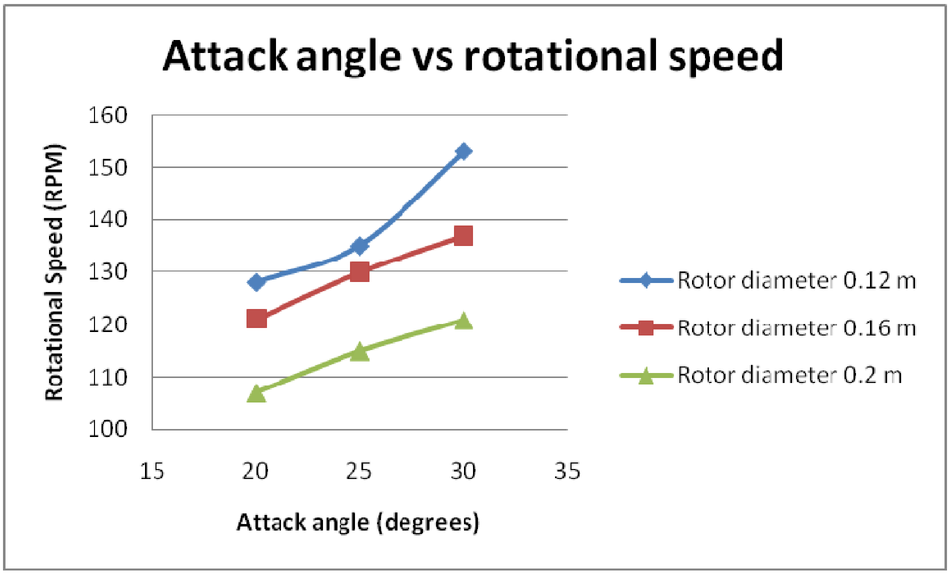

Fig. 6: Graph Portraying Attack Angle vs Rotational Speed

A model was developed for the rotaional speed based on the experimental data considering the effect of attack angle of blade, rotor dia. and wind velocity. The results for rotaional speed were analysed using the least square method on a DataFit software. The rotational speed model is expressed as below.

$R = 3.187*(D^{-0.42}) * (W^{1.54}) * (B^{0.21})$ (2)

Where R is the Rotational Speed, D the rotor diameter of the turbine,W the Wind velocity
B is the attack angle of the blade

4. CONCLUSION

1. Rotaional speed is inversely proprtional to the rotor diameter of the turbine
2. The most influential parameter affectiing the performance of a wind turbine is the wind velocity. The rotational speed increases with increase in the wind velocity.
3. Increase in the attack angle of the blade also increases the rotational speed of the turbine. But it's influence on the rotational speed is not as significant as that of the wind velocity.
4. The obtained results from the experimentation are in close co-ordination with previous literature.
5. The empirical relation obtained can be used to set up a wind turbine to maximize its output

REFERENCES

[1] Solum A, Deglaire P, Eriksson S, Stalberg M, Leijon M, Bernhoff H., Design of a 12 kW vertical axis wind turbine equipped with a direct driven PM synchronous generator. EWEC – European Wind Energy Conference & Exhibition, 2006.

[2] Deglaire P, Eriksson S, Kjellin J, Bernhoff H., Experimental results from a 12 kW vertical axis wind turbine equipped with a direct driven PM synchronous generator. EWEC, 2007

[3] M. El-Samanoudy, A.A.E Ghorab, Sh.Z. Youssef, Effect of some design parmaters on the performance of a Giromill vertical axis wind turbine, Ain Shams Engineering Journal (2010) 1, 85-95

[4] Hwang In Seong, Hwang Chang Sup, Min Seung Yong, Jeong InOh, Lee Yun Han, Kim Seung Jo, Efficiency improvement of cycloidal wind turbine by active control of blade motion. 16th International conference on adaptive structures and technologies, October 9–12, Paris, France, 2005