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Influence of Concave Guide Vane at Different Tilt Angles on Savonius Wind Turbine Performance

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***Abstract*—this work numerically studied the influence of tilt angle in concave guide vane to increase Savonius rotor performance. Guide vane is one of additional device that its function is for directing wind stream onto concave blade and deserves as obstacle of the wind that flowing onto convex blade. That way increased wind speeds to the rotor, consequently it produced higher power coefficient and the Savonius rotor performed better performance. four designs of guide vane were arranged in this study. The design of guide vane at tilt angle 40°,50°, 60° and 70° The result concluded that tilt angle in guide vane affects the performance of Savonius rotor. The power that generated by the rotor with guide vanes at 50° increase significantly compared with Savonius rotor without guide vane. The maximum power coefficient improvement was attained up to 78.2%.**

***Key Words*—wind energy, wind turbine, guide vane, savonius rotor performance, tilt angle, CFD**

I. INTRODUCTION

Vrtical-axis wind turbines (VAWTs) have been tested to be effective devices to extract energy from the wind. VWATs have been used to generate mechanical and electrical energy at a range of scales, from small-scale applications through the large-scale electricity production [1]. One of (VAWTs) is Savonius wind turbine. It has simple structure, relatively low operating speeds, and an ability to capture wind from any directions. However, it has low aerodynamic efficiency [2]. Researchers worked to enhance the Savonius turbine performance by changing the structure of the turbine. Kamoji et al [3] and Gupta et al [4] studied the aerodynamic characteristics of a modified Savonius turbine with helical blades, while Golecha et al [5] and Altan and Atilgan [6] [7] placed a guide vane in front of the turbine to deflect flow for the returning blade. McTavish et al [8] proposed a modified blade shape and carried out both steady and transient CFD simulations. Kamoji et al [9] and Kacprzak et al [10] studied the performance of modified turbines with spline-type and Bach-type blades, with an increase in efficiency 16% found in the case of using spline-type blades. Tian et al [11] carried out CFD simulations of Savonius with elliptical blades. It is noted that the most recent studies use numerical methods, followed by a comprehensive verification with or without validation, to study the effect of rotor configurations. CFD models allow for performing a relatively affordable analysis of the most promising improvements of diverse devices or processes as the first step before a real prototype is built and tested. The present paper purposes to examine numerically the influence of guide vane designs towards improving of Savonius performance. Designs of guide vane introduce in this work at different tilt angles.

II. CHARACTERIZATION OF SAVONIUS WIND TURBINESPAPER

Every Savonius wind turbine is characterized by the swept area AS. This area influences the energy output of the turbine, and the larger it is, the more energy the turbine collects

$$As = H * D \tag{1}$$

Where
H is the height of the turbine
D is rotor diameter [12].

The tip speed ratio of the rotor is defined by the equation:

$$\lambda = \frac{vrotor}{v} = \frac{\omega d}{v} \tag{2}$$

Where
v is the wind speed
ω is the angular velocity of the turbine
d is the diameter of the semi-cylindrical blade [12].

The torque coefficient Ct is the ratio between the torque in the rotor and the theoretical torque that the wind can cause:

$$C_T = \frac{T}{T_o} = \frac{T}{(1/4\,\rho\, v_1^2\, A_s\, d)} \tag{3}$$

Where
T is the torque in the rotor
ρ is the air density.

The power coefficient Cp is the ratio of the extracted power from the wind to the available power in the wind:

$$C_p = \frac{P}{P_o} = \frac{T * \omega}{(1/2\,\rho\, v_1^3\, A_s)} \tag{4}$$

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Using these factors, we can learn about the turbine's characteristics and analyze its performance.

III. Methodology

The aerodynamic characteristics for the Savonius rotor blades were studied to find highly efficient Vertical Axis Wind Turbine. This work is divided into two parts. The first part is numerical investigation. This computational investigation was done using ANSYS software. The flow field was designed on a 2-D model. The mesh was generated with ANSYS and basic investigation was run on FLUENT to determine the torque coefficient. And values of velocity and torque are extracted and then used to calculate torque and power coefficient. The second part is a comparison numerical and experimental results to make a final conclusion.

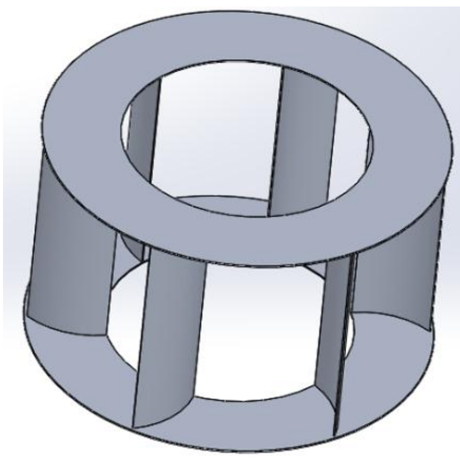

Figure 1. design of guide vane.

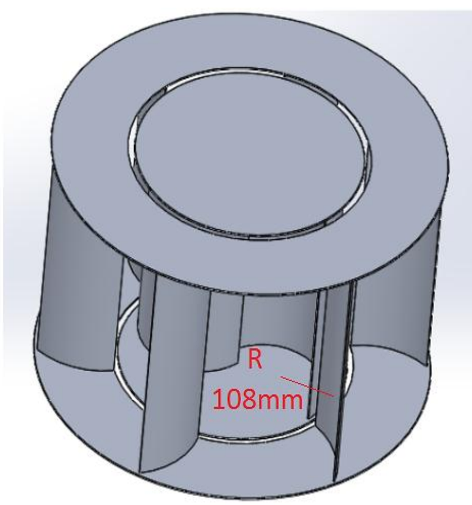

Figure 2. Design of shape concave of guide vane.

IV. Results

A series of simulation has been conducted using ANSYS software. The results were taken from simulation is torque (T) at various wind speed (v) in order to evaluate Savonius wind turbine performance. Torque coefficient of Savonius wind turbine with concave guide vane increased smoothly as shown in Figure 3 at each velocity. There was increasing of torque coefficient compared to the Savonius wind turbine without guide vane design. Maximum torque coefficient (Ct) that produced by the Savonius wind turbine without guide vane was 0.1869 at the wind speed 8.6 m/s and 0.1685 at 9.6 m/s. The Savonius wind turbine with concave guide vane attained of 0.271 at 9.6 m/s which means increased about 62.17%.

Torque increases regularly with the concave guide vane design at an angle of 50° as it shows in Figure 4 This is due to the guide vane blocked up the wind on the convex blade and directed the wind smoothly into the concave blade of a turbine. It consequently increased Savonius wind turbine rotation, so that the Savonius wind turbine generated higher power than the Savonius wind turbine without guide vane at all wind speed.

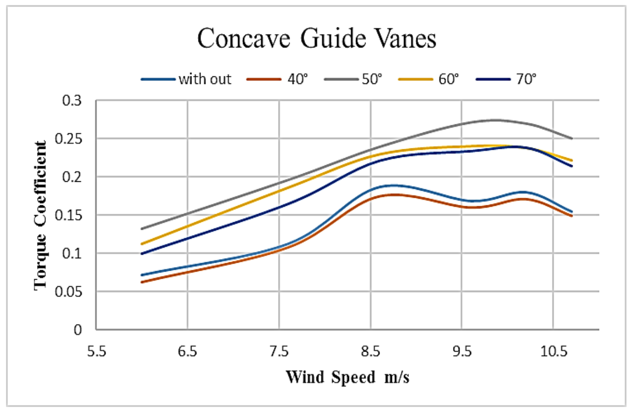

Figure 3. Variation between Torque Coefficient and wind speed with concave guide vanes at different tilt angle.

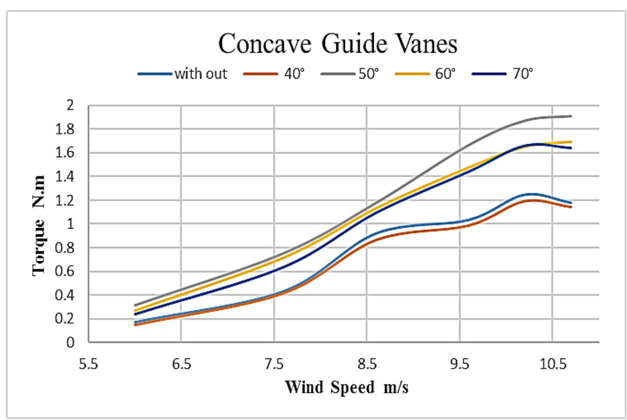

Figure 4. Variation between Torque and wind speed with concave guide vanes at different tilt angle.

Maximum torque of Savonius wind turbine with concave guide vane was 1.910 N.m at 10.7 m/s that is improves about 65.4% compared to maximum torque of Savonius wind turbine without guide vane, and minimum torque was 0.315 N.m at 6 m/s that is improves about 54.2%.

There is increase of power that generated by Savonius wind turbine accordingly with the increase of wind speed. Figure 5 illustrates that the addition of guide vane increased the power coefficient significantly compared to wind turbine without guide vane. The maximum power coefficient of Savonius wind turbine without guide vane was attained 0.1443 at 8.6 m/s. The maximum power coefficient of Savonius wind turbine with concave guide vane 0.18452 at the same wind speed. The power coefficient increased about 78.2%.

Figure 6 show the pressure distribution (pa) on the blades. The high-pressure area shows on the concave side and the low-pressure area on the convex side. The difference in pressure between the convex and concave sides of the blades causes the turbine rotating.

V. Conclusion

In present work, a series of simulation has been carried out. This simulation used two-blade Savonius wind turbine without guide vane and with guide vane at different tilt angle. The following conclusions can be drawn:

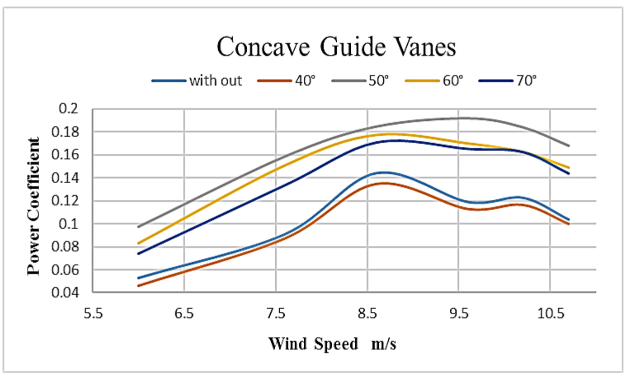

Figure 5. Variation between power coefficient and wind speed with concave guide vanes at different tilt angle.

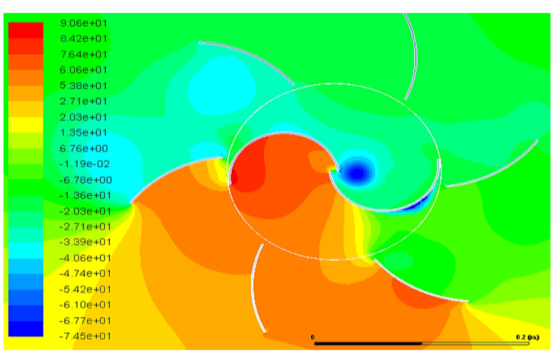

Figure 6. Static pressure Contours for 50° and 10.6 m/s.

1) The best tilt angle to improve Savonius wind turbine performance is 50°. The Cp that attained by turbine increases up to 78.2% compared without guide vane.
2) It has been proven that the addition of guide vane supports the improvement of the Savonius wind turbine. The guide vane helps to block up wind direction on to convex blade and direct it to concave blade. They are able drive and prevent the wind that might be escaped to the upper or bottom sides.
3) Coefficient of power (Cp) increases accordingly with the increase of wind velocity.

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