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Performances of Savonius Rotor with Addition Guide Vanes

Budi Sugiharto*‡, Sudjito Soeparman**, Denny Widhiyanuriyawan**, Slamet Wahyudi**

* Mechanical Engineering, Faculty of Science and Technology, Sanata Dharma University,Yogyakarta 55282, Indonesia
** Mechanical Engineering, Faculty of Engineering, Brawijaya University, Malang 65144, Indonesia
(sugih@usd.ac.id, sudjitospn@yahoo.com, denny_malang2000@yahoo.com, slamet_w72@yahoo.co.id)

‡ Corresponding Author; Budi Sugiharto, Tel: +628122732791, sugih@usd.ac.id

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Abstract- This paper aims to improve the performance of Savonius rotor with the addition of guide vanes. Guide vanes with angle of 45° against tangent are placed around the rotor with the aim of reducing the negative torque to the returning blade. Guide vanes are used with variations in the number of 4, 8 and 16. The analysis was conducted by simulation using Computational Fluid Dynamic (CFD) and experiment. The performances of Savonius rotor with 16 guide vanes was of 33% higher than without guide vanes.

Keywords: Savonius rotor, guide vanes, negative torque, performance

1. Introduction

Savonius is one type of vertical axis wind turbines, used for converts wind energy into mechanical energy. Savonius rotor is made up of two semicylinders called blades, which are placed in between two horizontal discs and the centers of which are arranged like the letter S. The advantage of the Savonius rotor is a simple design and construction. It receives wind from any direction; and it can work at low wind speeds and has high torque. The weakness of Savonius rotor is that it has a low coefficient of power (15%). The working flow on Savonius rotor had been investigated by Nakajima et al. [1,2]. There are six flows that affect the performance of the rotor, as in Fig. 1. Flow (I) attached flow along the advancing blade' convex side, flow (II) dragging flow form the advancing blade's convex surface to the returning blade's concave side, flow (III) provide back pressure on the returning blade's concave side form advancing blade's concave surface. Flow (IV) against the rotor motion on the returning blade and it results in reduced power. Flows (V) and (VI) are a vortex behind the blade which inhibits rotor motion. The first three flows which provide a positive performance and on the other hand, the last three flows of the give negative performance.

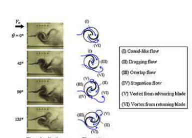

Figure 1. Flow patterns on a Savonius rotor [1]

Some researchers have increased the power coefficient with modifications. Irabu and Roy [3] in their study put the rotor in the guide-box tunnel. The obtained results showed power coefficient increased to 1.23 times of the rotor without the box, and to 1.5 times with three blades. Mohamed et al [4] added the obstacle shielding in front of the returning blade, which aims to eliminate the negative

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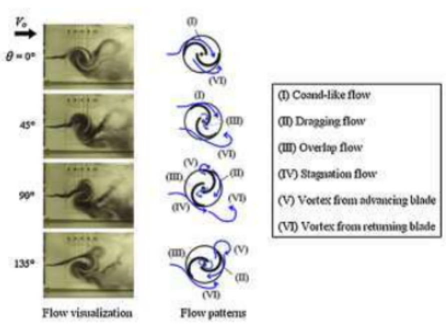

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This paper will be observing the addition of guide vanes around a Savonius rotor. The guide vanes are a wind deflector plate that is both simple and cheap as it is composed of flat acrylic sheets. In static conditions, the influence of guide vanes on the Savonius rotor will be analyzed both numerically and experimentally.

2. Research Methods

Savonius rotor is made from split of PVC pipe with diameter of d = 21.5 cm with overlap ratio e = 15% and end plate diameter D_o= 41 cm, as in Fig. 2. The variations of 4, 8 and 16 guide vanes are placed around the rotor, as in Fig. 3. The direction of the guide vanes was 45° from the tangent end plate and 1.13 cm from the edge of the end plate. Gupta et al [8] at analysis Savonius rotor with CFD, a two-dimensional computational unstructured mesh model was developed for the rotor in ANSYS. A k-ε turbulence closure model with standard wall treatment function was selected. A second order upwind discretization scheme was adopted for pressure velocity coupling of the flow. The sequential algorithm, Semi-Implicit Method for Pressure-Linked Equation (SIMPLE) was used for solving all the scalar variables. The flow was simulated on steady-state condition, and stationary was considered for the buckets. The boundary conditions in simulation following wind from the left side with a wind speed of 5 m/s, exit on the right side with the atmospheric pressure is equal to 101,325 Pa. The analysis of the rotor in the static, the rotor angle is θ = 0°, 45°, 90° and 135°. The material flow is air with a density of ρ = 1.225 kg/m^3 and a dynamic viscosity of μ = 1.7894 x 10^{-5}. The rotor worked at atmospheric pressure conditions is 101,325 Pa. The results of the simulation are displayed in the form of velocity and pressure contours. Experiments are being conducted in a wind tunnel with a size of 120 cm x 120 cm x 240 cm. Wind speed used in experiment is 5 m/s.

The experiment performed with the size and conditions similar to the simulation. Braking load is varied to determine the generated torque. Tachometer was used to measure rotor rotation. Results of torque and rotation are used to determine the coefficients of power. Tip speed ratio (tsr) was determined from the ratio of the speed of the edge of the rotor to the wind speed.

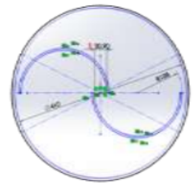
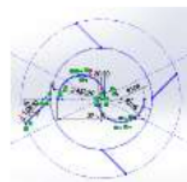
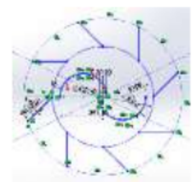


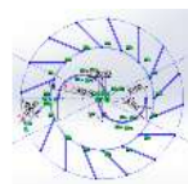
Figure 2. Dimension of Savonius Rotor



a. 4 guide vanes



b. 8 guide vanes



c. 16 guide vanes

Figure 3. Savonius Rotor with Guide vanes

3. Results and Discussion

3.1. The velocity field

Wind velocity field around the rotor at 0°, 45°, 90° and 135° rotor angle against the wind direction is shown in Fig. 4. Differences of colors, from dark blue to red indicate the wind speed from 0 up to 8 m/s. The difference velocity field that occurred in the advancing blade that is greater than the returning blade greatly affected the rotor performance. At the rotor angle θ = 0° occurs the lift force on the convex side of each blade which resulted in the rotor to spin clockwise, winds through overlap toward the the returning blade's concave side. At the rotor with 4 guide vanes, Coanda flow going on behind the returning blade's convex side so that differences that occur is quite small with the advancing blade's convex side. Thus, the torque that occurs is lower when compared to the rotor without guide vanes. At rotor angle θ = 45° shows a major change from the rotor without guide vanes as compared to rotor with guide vanes. Rear the advancing blade's convex side on the rotor without guide has happened vortex being on the rotors with directional wind speed increases so that the flow is still going a Coanda-like flow. The increased power is accompanied by the flow which flowed through the overlap increases. The biggest difference in the speed of the wind through the advancing blade against the returning blade occurred at the rotor with 16 guide vanes that are shown with the different colors displayed on the front rotor. At rotor angle θ = 90°, although as the most gets wind but stagnation point in advancing blade and returning blade difference are small enough so that the power is getting smaller. The rotor performance at rotor angle θ = 135° was not good. In addition to the differences in distance between the stagnation points of the advancing blade against the small returning blade, shift of stagnation point is closer to the axis of the shaft. Rotor with 16 guide vanes has the best performance compared to the others.

The vortex that occurred behind the rotor area causes a decrease in the static torque, characterized by dark blue area. In the rotor with guide vanes, vortex occurrence is reduced and shifted to the back of the guide vanes. Increasing the number of guide vanes will produce the smaller vortex occurrence. Decrease vortex that occurs will increase the static torque.

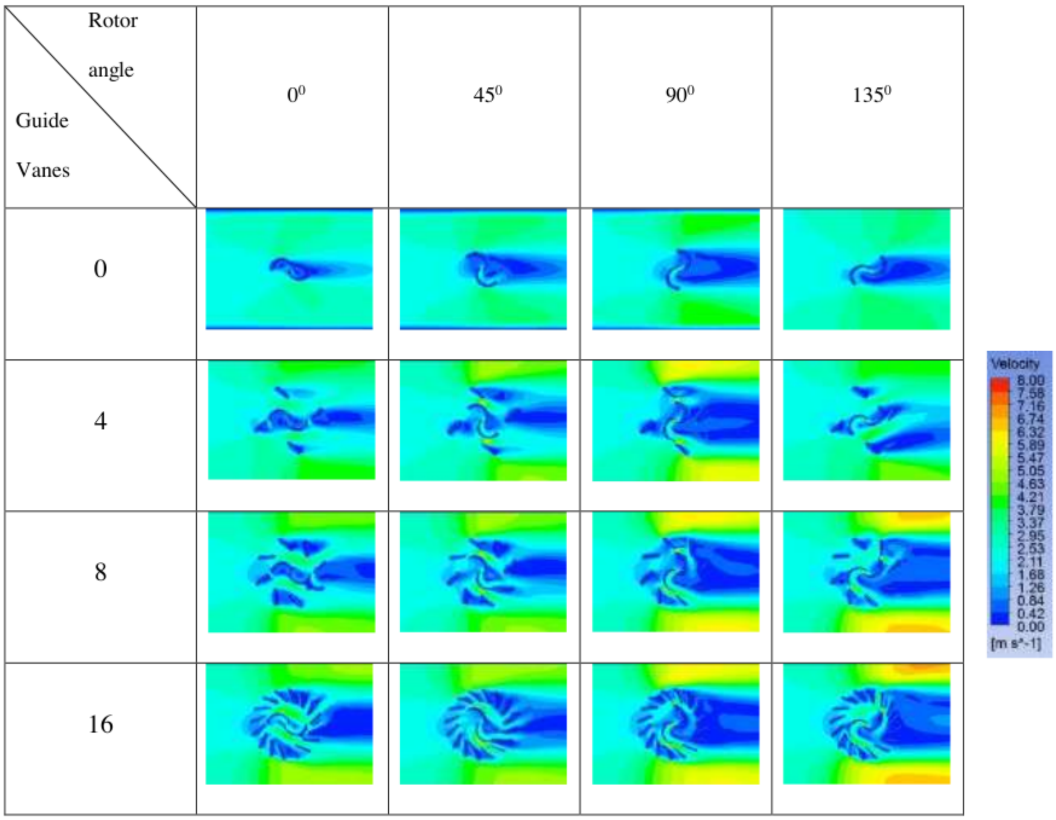


Figure 4. The velocity field static conditions at rotor angle of $\theta = 0^0, 45^0, 90^0$ and 135^0.

3.2. Pressure distribution

The pressure distributions in the rotor with and without the guide vanes are shown in Fig. 5. Each image is determined at a pressure of 101,315 Pa – 101,355 Pa. The regions with low wind speeds had great pressure and vice versa. Large differences in pressure on the advancing blade against returning blade, causing the measure of torque that occurred.

The highest pressure of Savonius rotor without guide vanes occurs at rotor angle θ = 90°, this happens because the cross section of the rotor dealing directly with the most extensive wind. An unobstructed area expanded with increasing angle of the rotor blade with guide vanes, which resulted in a large increase of pressure. The difference in pressure on the advancing blade against returning blade biggest turning occurs at rotor angle θ = 45°. The comparison between the pressure difference on the advancing blade against returning blade, rotor with 16 guide vanes having the greatest difference.

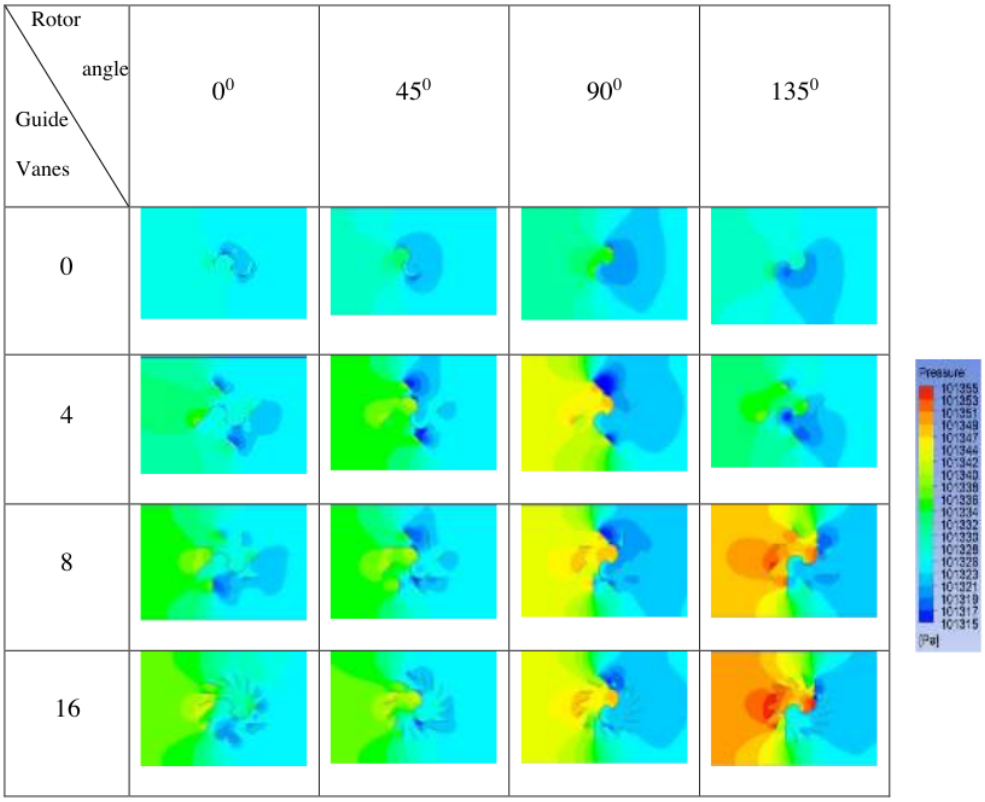


Figure 5. The pressure distribution static conditions at rotor angle of $\theta = 0^\circ, 45^\circ, 90^\circ$ and 135°.

3.3. Torque, power coefficient.

Comparison of numerical and experimental static torque at Savonius rotor without guige vanes to the rotor angle changes every 15° from 0° up to 180° was shown in Fig. 6. The difference between the numerical and experimental results is maximum 20%, so in turn the experimental results were used. The comparisons between the rotor without and with guide vanes by experimental are shown in Fig. 7. The highest torque occurs at rotor angle 45° and the lowest in 150°. The additional guide vanes around the rotor increase the static torque. When the rotor angle θ = 45°, rotor with 4 guide vanes, vortices occurred in front of the rotor so that the static torque that occurs is lower than the rotor without guide vanes. The maximum torque is obtained at the rotor with 16 guide vanes of 0.38 Nm or 58% greater than the rotor without guide vanes. Static torque determines the rotor's performance when the initial conditions of the rotor would rotate. When the rotor stops at rotor angle of 120° up to 165° it is quite difficult rotor began to spin when the wind speed is low. Large wind speed increases the torque to initiate rotor rotates.

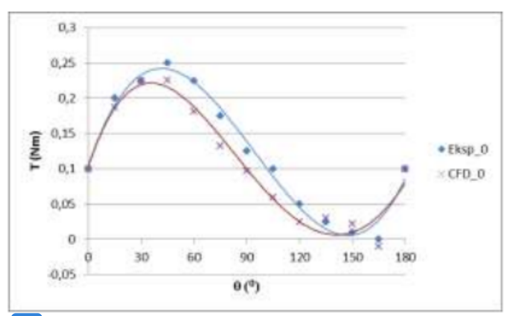


Figure 6. Static torque relationship with the rotor angle

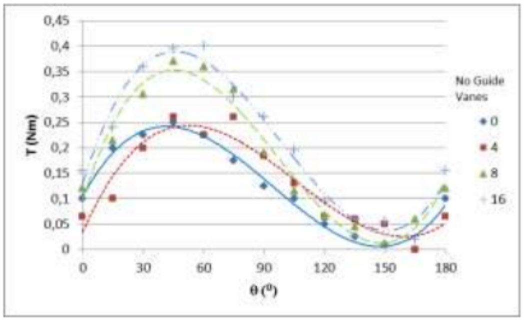


Figure 7. Static torque relationship with the rotor angle

The torque generated by the rotor with guide vanes is larger than the rotor without guide vanes, as shown in Fig.8. The maximum no-load rotor rotation is 400 rpm. Rotor works with high torque at low speed and optimum in round 200 rpm. Rotor with 16 guide vanes has the greatest value compared to the other. The torque occurs at low rpm, the torque is reduced further by making the rounds of the rotor increases. Rotor with 8 guide vanes has a higher torque than the rotor without guide vanes with the rotation of less than 200 rpm, the rest of the 8 guide vanes rotor has a lower torque. This is due to the rotor speed above 200 rpm, guide vanes impeding the working flow of the rotor. The torque on the rotor with 4 guide vanes is lower than the rotor without guide vanes.

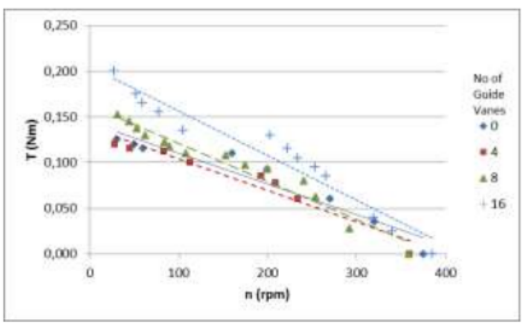


Figure 8. Torque relationship with the rotation of the rotor

Comparisons of Savonius rotor power coefficient with and without guide vanes are shown in Fig. 9. The coefficient of maximum power at tsr is about 0.8, or about 200 rpm rotor rotation. The maximum power coefficient Savonius rotor with 16 guide vanes was 22% or an increase of 33%. The rotor with 4 and 8 guide vanes has a value of lower than the rotor without guide vanes. Power coefficient is zero at tsr about 1.5 means that the rotor is not given load or rotor spin freely.

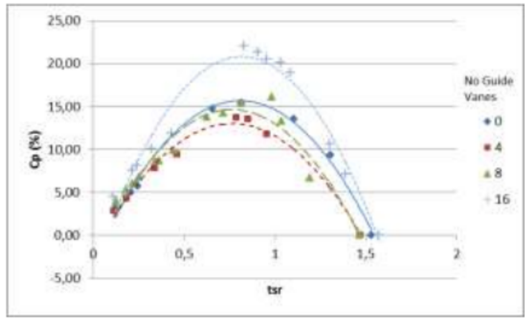


Figure 9. Power coefficient relationship with tsr

The Savonius rotor with guide vanes does not always have a positive impact on the overall performance of the rotor, such as the power coefficient. But the Savonius rotor with guide vanes always brings a positive effect on the initial or static torque, meaning that the presence of guide vanes with the same wind speed rotor is started spinning.

4. Conclusion

From the research that has been done, it can be concluded that

- Savonius rotor with guide vanes increases static torque values.
- The torque on the rotor with 4 guide vanes is lower than the rotor without guide vanes.
- The maximum static torque is at the rotor angle θ = 45°.
- The best rotor performance is on 200 rpm.
- Guide vanes with the number 16, increases the power coefficient of 33%.

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