Experimental study of helical savonius rotor profiles with different number of blade

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Abstract. This research is about the savonius wind turbine which was made in the form of a prototype as a simple student learning media. The goal is the students understand the process of converting wind energy into mechanical energy. The turbine model used is helical savonius rotor with U, S, and L profile on three blades and four blades. Tests carried out using wind tunnels. The test results show that helical savonius rotor with three blades provides better performance than four blades. The best turbine power is obtained in the L profile with three blades which is equal to 1.62 watts. While the best power coefficient is obtained from the S profile with 3 blades with a power coefficient value of 0.122.

1. Introduction
The wind turbine is one of the media to convert wind energy into electrical energy [1]. For reducing the utilization of fossil energy, renewable energy such as wind energy is the best way to provide green power, clean and sustainable [2][3]. There are two main classification of wind turbines, namely vertical axis wind turbines (VAWTs) and horizontal axis wind turbines (HAWTs) [4]. Both types of turbines have different characteristics. The horizontal axis wind turbines are suitable to be applied in areas with high wind speeds. Conversely, if an area has a low wind speed, then a wind turbine with a vertical axis is the recommended turbine model. Besides, vertical axis wind turbines can capture wind from all directions [5], because the laying of the blades is attached to the vertical shaft. This is the advantage of vertical axis wind turbines, even though the power generated is not as maximum as horizontal wind turbines [6][7]. Therefore this research will focus on vertical wind turbines. One of the reasons is because Indonesia has the potential for a low average wind speed of 2.7-4.5 m/s [8].

The type of vertical wind turbine that will be studied is the helical savonius rotor. Helical savonius wind turbines have a simple shape and construction so that the manufacturing process does not require the expensive costs [4]. Savonius wind turbine is a type of wind turbine that is driven by drag. This turbine consists of two, three, or four blades which are arranged as seen from above as forming the letter [9].

The research was carried out by constructing a prototype of a simple helical savonius rotor. The aim is as a learning medium for students. With the construction of this turbine, students can compare theoretical and practical lessons. The turbine will be built using several models of profile (L, S, and U) and also the number of blades.
2. Method

2.1. Turbin design

This study aims to design and create a prototype as a medium for student learning. The helical savonius rotor has constructed on a laboratory scale consisting of wind tunnels and blade construction. The number of blades varied into three and four. The profile is helical consist of three models U, S, and L. Blade has 800mm in high, 460mm of diameter, and made from aluminium.

2.2. Main parameters

The performance of helical savonius rotor can be revealed in several forms such as tip speed ratio (TSR) in equation (1), the wind power available (P_{available}) in equation (2), and coefficient of power (cp) in equation (3). TSR is a key element like of the wind turbines. TSR refers to the ratio of the wind speed to the wind turbine blade tips. P_{available} describes the process by which the wind generates mechanical or electric power. Cp is an indicator of the performance or the ratio of real electricity produced by a wind turbine divided by the total wind energy flowing through the turbine blades at different wind speeds. The formulas are given by [10]:

\[ TSR = \frac{2\pi Rn}{60u} \]  

(1)

Where \( R \) is the radius of turbine (m), \( n \) is the rotational speed of the rotor (Rpm), and \( u \) is wind speed (m/s).

\[ P_{available} = \frac{1}{2} \rho A u^3 \] 

(2)

Where \( \rho \) is the density of air (1.22 kg/m³), \( A \) is the swept area of blades (m²), and \( P_{available} \) is total power available from the wind (watt).
\[
cp = \frac{P_{\text{turbine}}}{P_{\text{available}}}
\]  

Where \(P_{\text{turbine}}\) is the power generated by the turbine (watt), \(P = I \text{ (ampere)} \cdot V \text{ (Volt)}\).

3. Result and Discussion

Measurement results in the field show that the wind speeds influence turbine performance. Figure 5 and figure 6 show the results of research on tip speed ratio and turbine power based on variations in three wind speeds.

Fig. 5 presents variations in wind speeds against the tip speed ratio value. From the graph, it appears that the tip speed ratio and turbine power increase when the wind speed increases, all model profiles and the number of blades show the same conditions. A three blades L profile produces a maximum TSR of 0.564 at a wind speed of 4.8 m / s. An S profile with three blades produces a maximum TSR of 0.513 at a wind speed of 4.5 m / s. While the S profile produces a TSR value of 0.465 on three-blades with a wind speed of 4.5 m / s. Figure 6 shows the value of turbine power based on variations in wind speeds. This condition is the same as TSR, which means an increase in wind speed, the power turbine produced also
increases [11]. The maximum turbine power obtained from the L profile is 1.62 watts at a wind speed of 4.8 m/s. The S profile is 1.378 watts and the U profile is 1.6 watts. All three were obtained from three-blades at wind speeds of 4.8 m/s. All of the results indicated that helical savonius rotor with three-blades have better TSR and power than four-blades.

Figure 7 shows the differences in TSR values and power coefficients of various profile models and the number of blades. The power coefficient values for the three profiles ranged from 0.029 to 0.122. The maximum value of the power coefficient is obtained from the S profile at three blades at TSR 0.5 with a value of 0.122. In general, all profile models show the same performance, the three-blades have a higher power coefficient than the four blades.

![Figure 7. TSR Vs CP for three and four blades in various blade profiles](image-url)
Helical savonius rotor with three blades show even speed with each turbine blades. This is due to the position of the vertical axis turbine provides a balance of wind speed when the first blade has passed through the wind and then forwarded to two blades and three blades, so the effectiveness of the flowing wind is able to be good for distribution to each side of the blade. Whereas in the 4 blades, the velocity distribution is more concentrated behind the blades, and high oscillations will be unfavorable for rotor rotation. This causes resistance to the blades so that some wind flow forces are not entirely distributed to push the blades.

The higher the speed distribution that occurs in the rotor the better the turbine performance, because it is possible to provide thrust to the blades and be forwarded to the rotor shaft, so as to produce mechanical energy to drive the generator.

4. Conclusions
Savonius wind turbine testing with three profile models using three and four blades has been carried out. The test results show that of the three profile models, the turbine with the number of blades 3 gives the best performance; this can be seen from the value of the turbine power and the power coefficient.

References
[1] Mandal AK, Rana KB, and Tripathi B 2020 Experimental study on performance improvement of a Savonius turbine by equipping with a cylindrical cowling Energy Sources, Part A: Recovery, Utilization, and Environmental Effects pp 1-19
[2] Mobashi M, Ayadi A, Chouaibi Y, Driss Z, and Tucciarelli C 2019 Performance study of a helical savonius hydrokinetic turbine with a new deflector system design Energy Conv. and Manag. 194 pp 55-74
[3] Bai HL, Chan CM, Zhu XM, and Li KM 2019 A numerical study on the performance of a Savonius-type vertical-axis wind turbine in a confined long channel 139 Renewable Energy pp 102–109
[4] Saad AS, El-Sharkawy II, Ookawara S, Ahmed M 2020 Performance enhancement of twisted bladed Savonius vertical axis wind turbines Energy Conv. and Manag. 209 112673
[5] Seralathan S, Ganesh CPVS, Venganna BPR, Srinivas NS, Chowdary BL, Hariram V, and Premkumar TM Simulation studies to analyze the static mechanical properties of helical Savonius vertical axis wind turbine blade Materials Today: Proceedings.
[6] Alom A, Saha UK 2019 Influence of blade profiles on savonius rotor performance: Numerical simulation and experimental validation 186 pp 267–277
[7] Wijianti E S, Saparin, 2019 The effect of blade type variations on savonius wind turbine performance IOP Conf. Ser.: Earth Environ. Sci. 353 012015
[8] Nurrohim Agus, 2012 Pembangkit listrik tenaga hibrid sebagai solusi kelistrikan di daerah terpencil Jurn Sains dan Tek. Ind. 14 pp 96-103
[9] Kamoji M A, Kedare S B, and Prabhu S V, 2009 Performance tests on helical savonius rotors Renew. Energy 34 pp 521–529
[10] Zemamou A M, 2017 Review of savonius wind turbine design and performance Energy Procedia 141 pp 383–388
[11] Wijianti E S, Saparin, Setiawan Y, and Karim A F 2019 Effect of Blade Profile Models on Savonius Wind Turbine Performance Prosiding SNTTM XVIII 2623-0313

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