Check for updates

NUMERIC ANALYSIS OF BLADES CURVATION OF SAVONIUS WIND TURBINE

Delffika Canra and Muhammad Luthfi[1], Ruzita Sumiati[2], Yusup Rohmat[1]

[1] Politeknik Negeri Indramayu, Indonesia
[2] Politeknik Negeri Padang, Indonesia
delffika.canra@polindra.ac.id, mhm.luthfi@polindra.ac.id, yusupnurrohmat@polindra.ac.id

Abstract. One promising source of renewable energy is wind energy. Wind energy is an abundant source of renewableenergy to produce clean energy. A wind turbine is a device usedto convert wind energy into kinetic energy. The average wind speed is 3m/s to 7m/s in Indonesia, classified as low wind speed. Savonius wind turbines can produce high torque values at low wind speeds. Making curvature variations in savonius wind turbine blades is one form of development to improve theperformance of these wind turbines. This study aims to determine the effect of blade curvature from 0% to 100% bladecurvature variations and wind speeds from 3m/s to 10m/s on thevalue of Coefficient of Power, Torque, and Rotational Speed. The method used is Numerical using CFD (Computational Fluid Dynamic) Solidworks software. As a result, the largest Coefficient of Power value is in the 10% blade curvaturevariation which is 52.0224% at 5.5m/s wind speed. The largesttorque value is in the 20% blade curvature variation which is 0.1399 Nm at a wind speed of 10m/s. Then, the largest rotationspeed value is in the 10% blade curvature variation which is 713.3005 Rpm at 10m/s wind speed.

Keywords: Savonius turbine; Coefficient of Power; Torque; and Rotational Speed.

1. Introduction

In recent decades, the need for renewable energy sources has increased along with the world's growing population and increasing energy consumption. One promising renewable energy source is wind energy. Wind energy is an abundant renewable resource for generating clean energy. Wind turbinesare one of the most commonly used technologies to convert wind energy into electrical energy.

Wind is moving air caused by the rotation of the earth and because of the difference in air pressure around it. The wind moves from a place of high air pressure to a place of low air pressure. When heated the air expands, the air that has expanded will become lighter so it rises. When this happens, the air pressure drops because there is less air. As the surrounding coldair flows to a place of low air pressure, it shrinks to become heavier and then drops to the ground. Above the ground, the airbecomes hot

© The Author(s) 2024
M. U. H. Al Rasyid and M. R. Mufid (eds.), *Proceedings of the International Conference on Applied Science and Technology on Engineering Science 2023 (iCAST-ES 2023)*, Advances in Engineering Research 230,
https://doi.org/10.2991/978-94-6463-364-1_47

and rises again. The flow of rising hot air and falling cold air is due to convection [1].

The average wind speed in Indonesia is 3m/s to 7 m/s, whichis considered low wind. So, to take advantage of this low speed

wind, the savonius type wind turbine can rotate at low wind speeds. The advantage of this savonius wind turbine is that it can produce relatively high torque even at low wind speeds, which is very good if it is developed to produce electrical energy [2].

Wind turbines are basically divided into two types, namelywind turbines that rotate on a horizontal shaft called Horizontal Axis Wind Turbines (HAWT) and Vertical Axis Wind Turbines(VAWT). Horizontal wind turbines are a type of turbine whoseturbine rotation axis is parallel to the wind direction in order toproduce power. While the wind turbine with this vertical axis type is a type of wind turbine where the axis of the wind turbineis perpendicular to the wind direction [3].

The following are the types of wind turbines according to Faisal Mahmuddin [4] states that:

1.1. Horizontall Axis Wind Turbine (HAWT)

HAWT is a turbine whose main shaft rotates in the directionof the wind. In order for the rotor to rotate properly, the wind direction is parallel to the turbine shaft and perpendicular to therotor rotation direction.

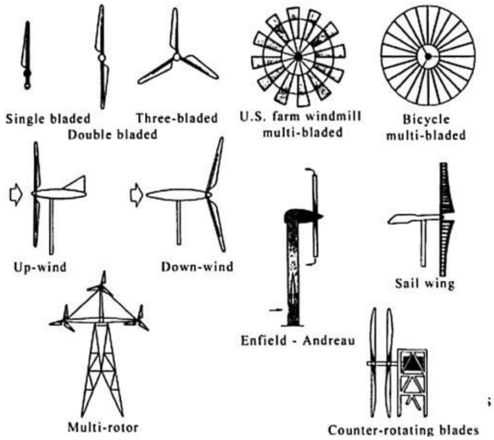

Fig. 1. Horizontal type wind turbine [5].

1.2. Vertical-Axis Wind Turbine (VAWT)

VAWT is an upright wind turbine whose rotor movement and also the shaft are parallel to the wind direction, so that the rotor can rotate in all wind directions. VAWT has advantages and disadvantages, the advantage is that it has a high torque soit can rotate at low wind speeds. While the disadvantages are, the wind speed at the bottom is very low so that if you do not use a tower it will produce low rotation and lower efficiencythan HAWT.

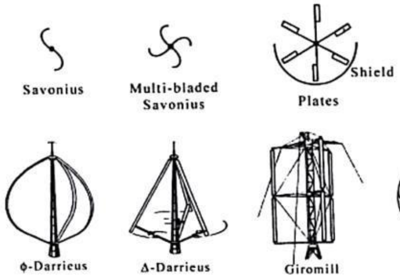

Fig. 2. Vertical type wind turbine [5].

Savonius wind turbine blade shapes can vary or have differences in blade height, blade width, curved angle, and the ratio between blade height and width. These factors affect the performance and efficiency of savonius wind turbines. Further research on the shape of savonius wind turbine blades could involve computer simulations, laboratory experiments and fieldtesting to obtain more accurate data on the performance of blades with different shape variations.

M. Akhlaghi & F. Ghafoorian [6] with the title "Investigation of Arc Angle Rotor Blade Variation Effect of Savonius Virtical Axis Wind Turbine on Power and Torque Coefficients Using a 3D Modeling". This research was conducted by analyzing the change in the number of arc angles,namely 180°, 150° and 200°. The method used for this researchis the 3D modeling numerical method. The goal is to find the value of the coefficient and torque. The results and 3D numerical research show that the highest power and torque coefficients are obtained with values of (0.0261) and (0.501), respectively. The value of the power coefficient can be seen inFigure 3 and the torque can be seen in Figure 4.

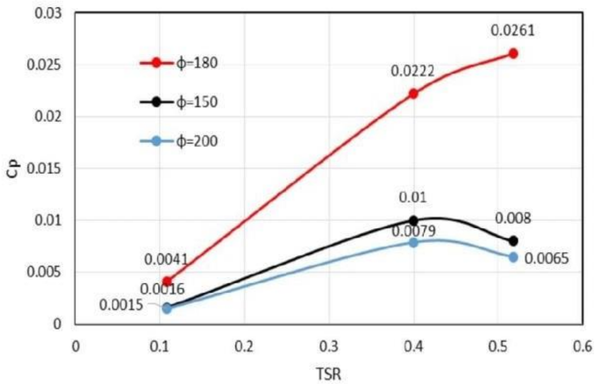

Fig. 3. Power Coefficient

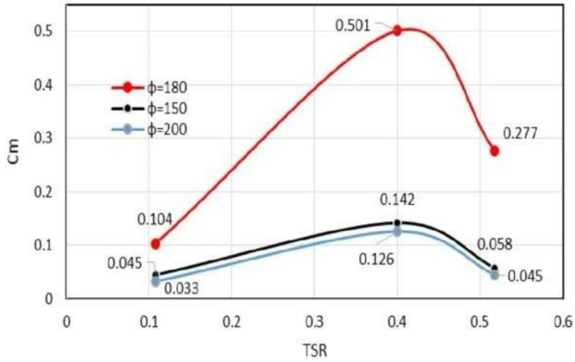

Fig. 4. Torque

Jamal [7] conducted research with the title "The Effect of the Number of Blades on the Performance of Savonius Turbines", where in this study, there are research objectives, namely increasing the performance of savonius wind turbines with variations in the number of blades and variations in air flow speed and the method used is experimental.

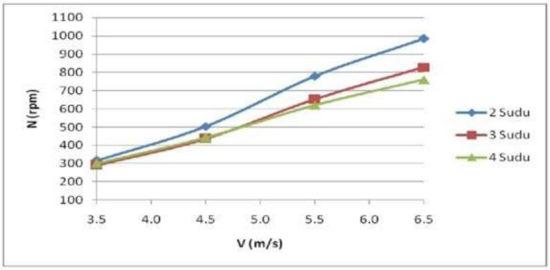

Fig. 5. Relationship between wind speed and turbine rotation

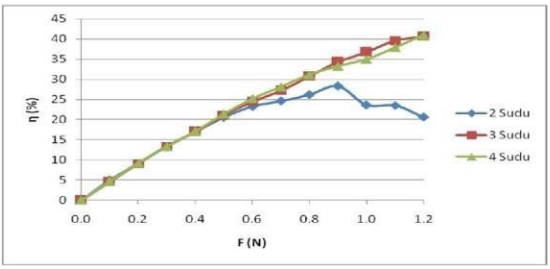

Fig. 6. Relationship between load and efficiency with different number ofturbine blades at 3.5 m/s wind speed.

The result of this research is that the turbine with 2 blades has a large rotation value compared to 3 blades and 4 blades, but the turbine with 2 blades has a low torque moment compared to the others, this is due to the low efficiency of the 2-

blade turbine at low wind speeds with high loads.

Delffika Canra, et al [8] conducted research with the title oftheir research, namely "Analysis of the Type-U Savonius WindTurbine Blade Arc Using Software". This research has the aimof getting more power and the method used is numerical.

Fig. 7. Radius of the blade

Fig. 8. Cross section width

The result of this research is that the turbine is designed with2 blades, the parameters that are varied are the geometry of thearc length and cross-sectional width. From the simulation results, the radius and cross-sectional width prove the influence of geometry in increasing turbine power by 7.78% and 19.76%,respectively. The blade variation produces the greatest power found in the R 75 blade variation, namely turbine power of
1.554 watts and wind power of 2.853 watts at a wind speed of 4.8m/s. Then the greatest power is also found in the blade variation with a cross-sectional width of 130, namely with a turbine of 2.020 watts and wind power of 3.709 watts at a windspeed of 4.8m/s.

Coefficient of Power and Tip Speed Ratio are both closely related to wind turbine performance and efficiency. The Coefficient of Power and Tip Speed Ratio graphs are useful tools in wind turbine analysis and planning, helping to determine the turbine's optimal operating point, andunderstanding turbine performance at various wind speeds.

According to Delffika Canra and Rachmatullah [9] "Coefficient of Power (Cp) and Tip Speed Ratio (TSR) are where wind turbines are approximately 0.3 while the ideal Cp is 0.5929”. for savonius wind turbines can be seen in Figure 9.

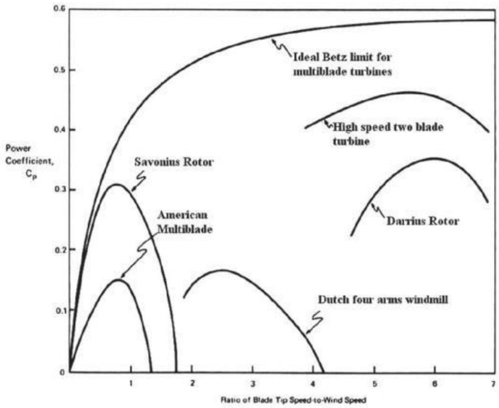

Fig. 9. Relationship between Cp and TSR

Wind turbines are energy conversion devices used in the power generation industry, pump drives and the rice milling industry. The good and bad performance of this wind turbine depends on the design of the turbine against the available wind energy potential [10].

In this study, the authors will analyze the results of blade shape variations. The blade variation used is the curvature of the blade, then a computer simulation will be carried out usingsolidwork software. The purpose of this research is to analyze the effect of turbine blade shape on Coefficient of PowerTorque and Rotational Speed.

2. Research Methods

In this research, the method used is Numerical using CFD (Computational Fluid Dynamic)

Solidworks software. The initial stage is to design a wind turbine with blade curvature variations in blade length. The design ratio for this study is 1:4,endplate dimensions 120mm x 1.2mm, blade dimensions 100mm x 400mm x R30mm x 1.2mm x curvature at blade lengthvaried from 0% to 100%.

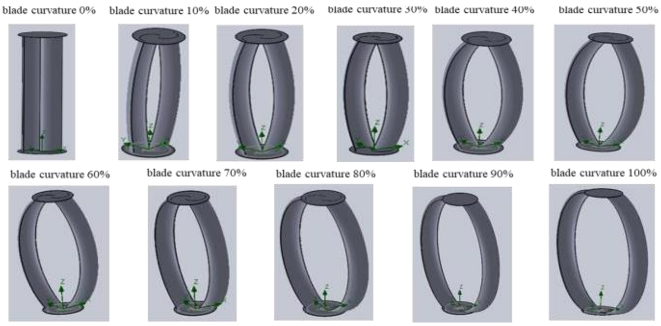

Fig. 10. Design drawing of the blade variation

The wind speed is varied from 3m/s to 10m/s. The simulationstage after design is to make a wind tunnel for air flow limitation. The data taken in this simulation is the difference in incoming and outgoing wind speeds. The data obtained will be processedand calculated theoretically to obtain turbine power, torque androtation speed as shown in Figure 11.

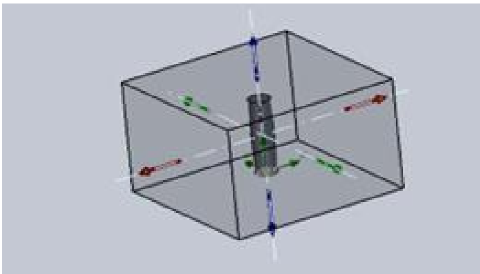

Fig. 11. Wind Tunnel Simulation

At the next stage of the simulation using solidworks software, the outgoing wind speed (v_2) can be generated. The outgoing wind speed can be seen in Figure 12.

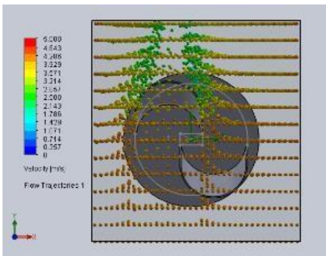

Fig. 12. Solidworks Results

According to Delffika Canra, et al [2] mentioned about the calculation using the Betz momentum theory where the wind speed (v_1) passes through a wind turbine blade that changes speed (v_2).

The following is the formula used to determine the value ofthe working turbine power.

$$P = \frac{1}{4} \times \rho \times A \times (v_1 + v_2) \times (v_1{}^2 - v_2{}^2) \qquad (1)$$

where P is turbine power, ρ is air density, A is surface area, and v is wind speed.

The Coefficient of Power (Cp) determines the performance of the turbine, where wind energy determines the amount of wind kinetic energy through the wind turbine blade, can be formulated as follows:

$$P_0 = \frac{1}{2} \text{ x } \rho \text{ x } A \text{ x } v_1{}^3 \qquad (2)$$

where P0 is the wind power.

The following is the Coefficient of Power (Cp).

$$C_p = \frac{P}{P_0} = \frac{\frac{1}{4} \text{ x } \rho \text{ x } A \text{ x } (v_1+v_2) \text{ x } (v_1{}^2-v_2{}^2)}{\frac{1}{2} \text{ x } \rho \text{ x } A \text{ x } v_1{}^3} \qquad (3)$$

Torque can be defined as a measure of the effectiveness of a force in producing rotation around an axis. Here is the formula for the amount of torque.

$$T = \frac{v^2 \text{ x } r^3}{\lambda^2} \qquad (4)$$

where T is torque, v is wind speed, r is blade width, and λ is tip speed ratio.

Meanwhile, the tip speed ratio can be calculated with the following formula.

$$\lambda = \frac{\pi \text{ x } D \text{ x } n}{60 \text{ x } v} \qquad (5)$$

where D = Blade diameter, n = Shaft / blade rotation, v = Wind speed.

3. Results And Discussion

By varying the curvature of the turbine blades, the results ofCoefficient of Power against wind speed can be seen in Figure13 and Coefficient of Power against Tip Speed Ratio can be seen in Figure 14.

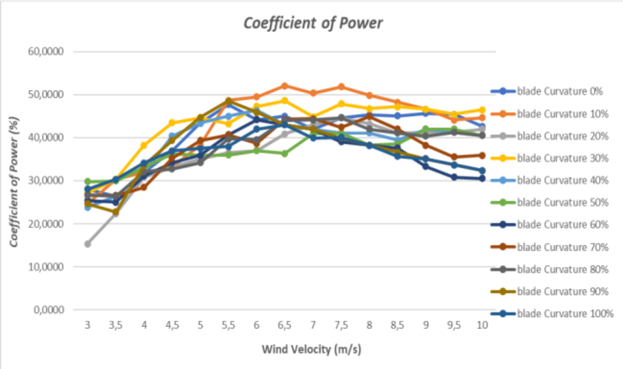

Fig. 13. Coefficient of Power against wind speed

In the graph above, it can be concluded that the highest Coefficient of Power value against Tip Speed Ratio is at 10% blade curvature of 52.0224% at a wind speed of 6.5m/s.

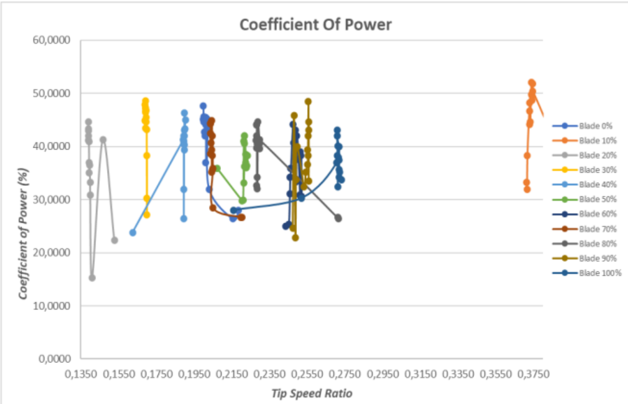

Fig. 14. Coefficient of Power against Tip Speed Ratio

In the graph above, the highest value of Coefficient of Poweragainst Tip Speed Ratio is at 10% blade curvature of 52.0224% with a Tip Speed Ratio value of 0.3738.

The following is a graph of the torque of all curvaturevariations at a blade length of 0% to 100%.

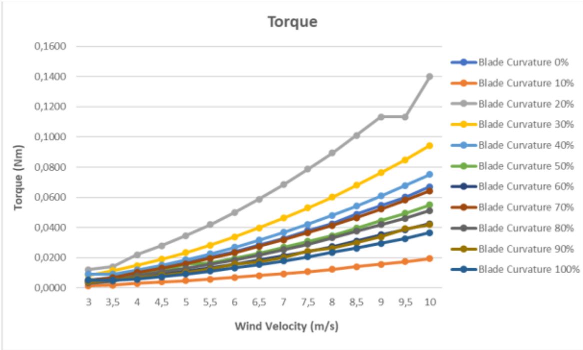

Fig. 15. Torque Results

In the graph above, the highest torque is at 20% highcurvature at 10m/s wind speed and the smallest torque is at 10%blade height curvature at 3 m/s wind speed.

The following is a graph of the rotation speed of all variations of curvature at blade height from 0% to 100%.

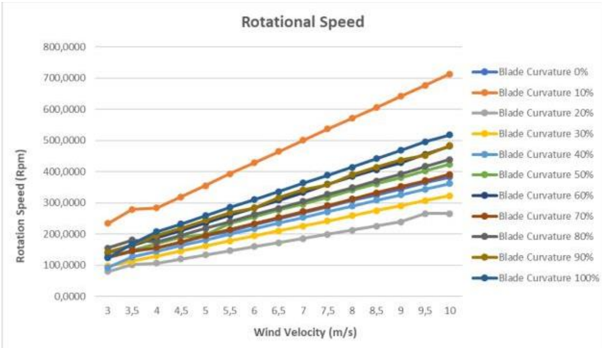

Fig. 16. Rotational speed results

In the graph above, the highest torque is at a high curvatureof 10% at a wind speed of 10 m/s and the smallest torque is at ahigh curvature of 20% blades at a wind speed of 3 m/s.

4. Conclusion

Based on the results of the research that has been carried out,with reference to the research objectives, the following conclusions can be drawn.

The effect of the shape of the blade on the value of Coefficient of Power is to get the greatest value of Coefficient of Power in the variation of the curvature of the blade height of10% compared to the curvature of the other blades which is 52.0224% at a wind speed of 6.5m/s. The effect of the shape ofthe blade on the Torque value and rotation speed is to get the largest Torque value at 20% blade height curvature variation compared to other blade curvature variations which is 0.1399 Nm and the largest rotation speed value is at 10% blade heightcurvature compared to other curvature blades which is 713.3005 Rpm at the same wind speed of 10m/s.

References

[1] Maidi Saputra.: "Kajian Literatur Sudu Turbin Angin untuk Skala Kecepatan Angin Rendah". *Jurnal Mekanova*. 2(1). April 2016. Universitas Teuku Umar. 2016.

[2] Delffika Canra., dkk.: "Analisa Aliran Angin pada Sudu Turbin Angin *Savonius* Tipe-U Berbasis *Software*". *Jurnal Teknologi Terapan*. 4(2). Indramayu: Politeknik Negeri Indramayu. September 2018.

[3] Muhammad Abdul Ghofur., dkk.: "Perancangan dan Simulasi Turbin Angin Sumbu Horizontal (TASH) dengan Variasi Jumlah *Blade* dan Variasi Sudut *Pitch* serta Analisis Power, *Torque* dan *Thrus* menggunakan Aplikasi *Q-Blade*". *Prosiding Seminar Nasional Teknologi Informasi dan Kedirgantaraan*. Yogyakarta: Sekolah Tinggi Adisucipto.Desember 2020.

[4] Faisal Mahmuddin., dkk.: "Studi Performa *Vertical-Axis Wind Turbine* (VAWT) Sebagai Pembangkit Energi Listrik pada *Floating Platform*". *Seminar Sains dan Teknologi Kelautan*. September 2018. Gowa: Universitas Hasanuddin. 2018.

[5] Yusuf Ismail Nakhoda dan Choirul Saleh.: "Pembangkit Listrik Tenaga Angin Sumbu Vertikal untuk Penerangan Rumah Tangga di DaerahPesisir Pantai". *INDUSTRI INOVATIF*. 7(1). 1 Maret 2017. Malang: Institut Teknologi Nasional Malang. 2017.

[6] M. Akhlaghi & F. Ghafoorian.: "Investigation of Arc Angle Rotor Blade Variation Effect of Savonius Virtical Axis Wind Turbine on Power and Torque Coefficients Using a 3D Modeling". *Journal of Renewable Energy Research and Aplication (RERA)*. 4(1). Iran: Iran Universuty of Science and Technology. 2023.

[7] Jamal.: "Pengaruh Jumlah Sudu Terhadap Kinerja Turbin *Savonius*". *INTEK Jurnal Penelitian*. 6(1). Makassar: Politeknik Negeri Ujung Pandang. 2019.

[8] Delffika Canra dan Rachmatullah.: "Uji Performa Hybrid Turbin Angin *Savonius-Darrieus Eggbeater*". *SINTEK JURNAL*. 16(1). Juni 2022. Indramayu: Politeknik Negeri Indramayu. 2022.

[9] Delffika Canra dan Rachmatullah.: "Uji Performa Hybrid Turbin Angin *Savonius-Darrieus Eggbeater*". *SINTEK JURNAL*. 16(1). Juni 2022. Indramayu: Politeknik Negeri Indramayu. 2022.

[10] Bambang Sulaksono.: "Perancangan Sudu Tangkap Terhadap Variasi Kecepatan Angin pada Turbin Angin". *Jurnal Ilmiah Teknobiz*. 9(2). Jakarta: Universitas Pancasila. 2019.

Open Access This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (http://creativecommons.org/licenses/by-nc/4.0/), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.