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The Optimization of Savonius Helix Wind Turbine Cut-in Speed with the Variation of Blades-twist Rotor and Number of Blades

Handy Prabowo[1], Danar Susilo Wijayanto[2*], Taufik Wisnu Saputra[3], Moh. Shafie Bakar[4]

[1,2,3] Mechanical Engineering Education Study Programm FKIP, Universitas Sebelas Maret, Indonesia

[4] Faculty of Electrical & Electronics Engineering, Universiti Malaysia Pahang, Malaysia

Email: danarsw@staff.uns.ac.id

ABSTRACT

Wind turbines are typically classified as Horizontal Axis Wind Turbines (HAWT) or Vertical Axis Wind Turbines (VAWT). VAWT has a superior ability to accelerate from rest to rotation than HAWT, allowing it to rotate the rotor even when the wind speed is low; additionally, the produced torque is relatively high. Using the Savonius helix VAWT is one of the numerous methods for enhancing VAWT performance. The effect of the number of blades and the blade twist of the rotor or the angle of rotation of the blades on the rotor from the bottom end to the top end on the speed cut generated by the VAWT Savonius helix was investigated experimentally. Variations in the number of blades used in the study included 2 and 3 blades, as well as 90°, 180°, 270°, and 360° for the rotor twist blades. In a wind tunnel, data was collected at wind speeds ranging from 0 to 5 m/s. The best performance research results were obtained With three blades, a twist angle of 180 degrees, and a cutting speed of 1.51 m/s. By modifying the Savonius Helix VAWT design in this study, it is possible to increase the efficiency and performance of turbines, mainly when used at low wind speeds, and the potential for using wind energy as a more efficient and sustainable alternative energy source.

***Keywords**: cut in speed, helical Savonius, number of blades, twist rotor blade, vertical axis wind turbine.*

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INTRODUCTION

In the industrial revolution 4.0, everything developed so rapidly in various fields that it had a major impact on human life, especially technology. To face the 4.0 industrial revolution, President Joko Widodo, on April 4 2018, opened the *Making* Indonesia 4.0 Program, which is a road map *and strategy* for entering the digital world era. Through the *Making* Indonesia 4.0 strategy, the government will focus on five main technologies, namely (1) *the Internet of Things*, (2) *artificial intelligence*, (3) *human-machine interfaces, (4)* robotic technology and sensors, and (5) 3D *printing technology* to increase Indonesia's domestic gross income and international competitiveness (Hartanto, 2019). With the increasing development of technology, which uses electricity as its primary power on average, the need for electricity is increasing (Suharyani et al., 2019). The final national electricity demand for 2019-2050 in the *Business as Usual* (BaU), *Sustainable Development* (PB), and *Low Carbon* (RK) sectors will increase with an average annual growth rate of (5.0%) each, (4.7%) and (4.3%) where the status of electric car and electric motorbike users currently reaches 229 *units* and 1,947 *units* with a production target in 2025 to reach 400,000 *units of* electric cars and 1.7 million *units of* electric motorbikes (Arinaldo et al., 2021).

Energy use in Indonesia is still dominated by non-renewable energy derived from fossils, especially oil and coal (Azhar & Satriawan, 2018). As evidenced by data from the Ministry of Energy and Mineral Resources (2019) that most of the power generation capacity installed in 2018 came from fossil energy plants, especially coal (50%), followed by natural gas (29%), fuel (7%) and renewable energy (14%). Based on research by Gernowo et al. (2016) found that the amount of CO_2 and other gases is increasing day by day due to the large number of additional carbon emissions produced by humans from burning fossil fuels. Strengthened by the opinion of Rizki Firmansyah Setya Budi (2013) & Achebe et al. (2020) that fossil-fuel power plants have quite large CO2 emissions because in producing electricity they burn carbon chains and significant CO2 emissions can also cause serious effects such as the greenhouse effect, depletion of the ozone layer, and health-related effects. Other. Even worse, according to Wai-Hoo & Sovacool (2014), it is cheaper for power companies to dispose of their waste in fly ash, CO2, *nitrous oxides*, sulfur oxides and methane for free.

The availability of fossil energy has recently decreased, so the price tends to rise (Tirono, 2012). This can be dangerous for the security of the Indonesian people's electrical energy, which is increasingly depleting; for this reason, renewable energy is needed. Renewable energy is energy that comes from renewable energy sources. Renewable energy sources are energy sources that can be used indefinitely and will never run out because they can be restored in a relatively short time (Azhar & Satriawan, 2018). Renewable energy sources include hydro, solar, wind, geothermal, biogas, biomass, and ocean waves.

Wind energy is a promising renewable energy source because of its availability (Abdelaziz et al., 2021). Several countries are currently considering wind energy as an essential source of energy. Moreover, developing countries have realized in the last decade the importance of wind energy (Mohamed et al., 2021). This energy can be used for power generation using the Wind Energy Conversion System (SKEA). Wind turbines can convert wind kinetic energy into electrical energy through generators (Wibowo, 2018). However, using wind energy in Indonesia has yet to receive special attention (Cendrawati et al., 2015). Setting up a wind power plant is more accessible than other plants.

Generally, wind turbines are divided into two types: *Horizontal Axis Wind Turbines* (HAWT) and *Vertical axis Wind Turbines* (VAWT). VAWT has the ability of the turbine to accelerate from rest until it can rotate better than

HAWT so that it is able to rotate the rotor even though the wind speed is low; besides that, the torque produced is relatively high (Alit et al., 2016). VAWT does not require an orientation system according to the wind direction. The VAWT is also very suitable for operating in the city centre due to its good response even to fast changes in wind direction. One of the most widely used VAWTs is the *Savonius turbine* (Kothe et al., 2020). The *Savonius* turbine is considered one of the best VAWTs for converting kinetic energy from the wind into mechanical energy at low wind speeds (Abdelaziz et al., 2021). The main disadvantage of the conventional *Savonius VAWT* is that it generates a negative torque at a particular blade rotation in the range between 135° and 165° and between 315° and 345° with significant torque variations (Kamoji et al., 2011). On the other hand, the *helical Savonius VAWT* produces a positive static torque coefficient in all blade rotors with better performance (Seralathan et al., 2022).

This type of wind turbine has a low rotational speed with high torque (Latif, 2013). In the *Savonius* helical VAWT study in India, the optimal wind turbine obtained the highest torque at a wind speed of 5.12 m/s (Micha Premkumar et al., 2018). This is evidenced that the Indonesian region has an average speed ranging from 3 m/s to 5 m/s (Ismail & Saleh, 2015). However, research conducted by (Azirudin, 2019) found that at the height of 30 meters at certain times, it reaches 4.50 m/s, while at other times, the wind speed is only 1.19 m/s, for it is necessary to design wind turbines that are suitable for low wind speed areas and can meet electricity needs (Sumiati & Amri, 2014). At very low wind speeds, it is most likely to optimize the *Savonius* helix VAWT in Indonesia. In another study, comparing one and two levels increased the strength coefficient of the two-stage *Savonius* helix VAWT by about 7.69% (Seralathan et al., 2022). Saha et al. (2008) investigated the helical VAWT *Savonius turbine* by combining the variables of semicircular and rotating shapes, number of blades and use of valves. The test speed was varied between 6 to 11 m/s, and it was found that the optimal number of blades was two for one, two or three levels. The two-stage rotor has a higher power coefficient. In another study, the VAWT *Savonius* helix used a 180° *twist* rotor, stating that *its overlaps ratio* 0 .242 is better than *an overlap ratio of* 0 or no *overlap* (Damak et al., 2018). Research conducted in the Syariah Hotel Solo building found that the ratio between the diameter and the height of a good rotor was 1:2 (Rizkiyanto, 2015). Besides it (Martinus et al., 2011) did a study with method simulation on VAWT Savonius helix with type rectangle length and ½ circle is obtained Power turbine on the ½ circle type better compared to type rectangle long with speed wind four m/s which is 9.335 of 47.6228 Watt (efficiency turbine by 19.6%).

There are various ways to improve the performance of the VAWT *Savonius* helix in order to produce high torque at high-speed in different winds where _ there is various method For optimizing the performance of turbine wind Savonius with modify or change design turbine Savonius did _ with additional use of *end plate*, change aspect ratio turbine height and diameter, change distance overlap ratio turbine, change amount bar, change thickness bar, change form blades, rotor changes with use *helical rotors*, and others (Akwa et al., 2012). Based on several studies described and the results known, a VAWT *Savonius* study will be carried out helix by modifying the rotor *twist blades* and the number of blades carried out by the experimental study method. It aims to determine the rotor *twist blades* and the number of blades that have the most effective performance at wind speeds in Indonesia.

RESEARCH METHODS

This research adopted the experimental method. The object of this research was the VAWT Savonius helix with variations in the number of blades 2 and 3 illustrated in Figure 1. The other samples were the variations in twist blades 90°, 180°, 270° and 360° rotors depicted in Figure 2. The test used the average wind speed in the Indonesian region, obtained through wind simulation using wind tunnels. The data collection method used in this study was measurement and calculation.

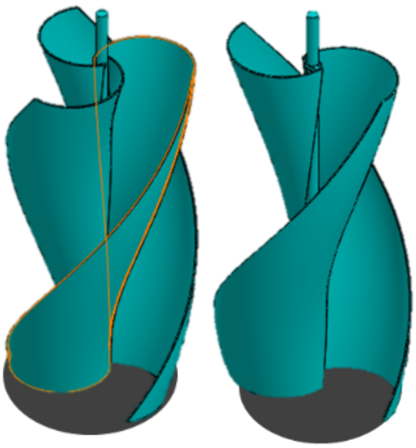

Figure 1. The Varied Number of Blades

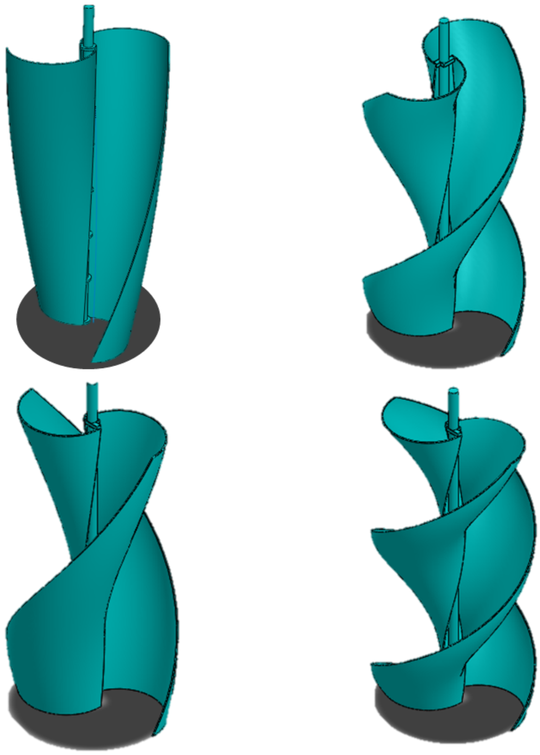

Figure 1. Variation Blade *Twist* Rotors

Various research instruments were adopted to help retrieve data from independent variables. The assessment instruments used include *wind tunnels, blowers, anemometer sensors, IR sensors, multimeters, arduino,* and *micro SD card modules.*

Figure 2. Speed Sensors round

As depicted in Figure 3, the rotation speed sensor uses a disk encoder sensor that works almost the same way as an IR sensor was an infrared light sensor used to detect obstacles or objects to detect obstructions or objects (Arfandi & Supit, 2019). The difference is *the disk encoder* sensor. This needs a plate with several symmetrical holes on the sides outside. These sensors will read How many sensors go through the hole in one seconds later _ converted to rpm.

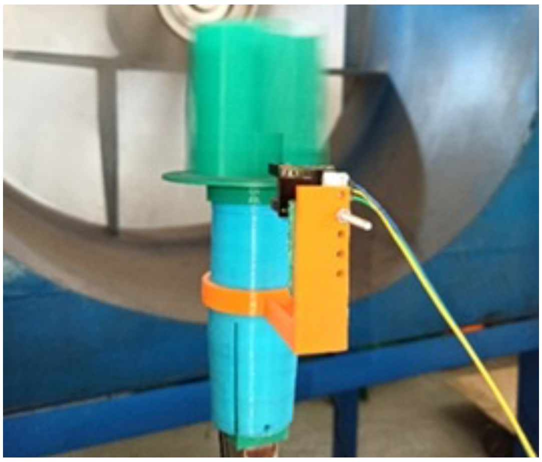

Figure 3. Speed Sensors Wind

The wind speed sensor in Figure 4 measured the speed of the wind exhaled by *the blower,* which Arduino processes. This sensor was a representation of the *disk sensor. The encoder,* as a reader of the rotational speed of the rotor, is converted to wind speed with an accuracy of 0.01 m/s with *the main chip* LM393 5 VDC and dimensions of 27.6 x 20 x 17 mm.

Figure 4. *Arduino Uno*

Figure 5 represents the Arduino Uno that represents the electronic board with an *open-source* microcontroller system that works independently. *Arduino* is used to process analogue data from sensors into digital to get the value from the sensor.

Figure 5. *Wind Tunnels*

The wind tunnel in Figure 6 exemplify a room used to simulate wind speed in wind turbine trials. The Micro SD Card modules as illustrated in Figure 7, stores all sensor data generated and stored on *SD card* through Arduino.

Figure 6. *MicroSD Card Module*

Data generated in the research was analyzed using descriptive investigation methods. Descriptive investigations were used to analyze data by comparing causal relationships with related factors (Gupta & Haldar, 2017). Quantitative data obtained was processed in tabular form. The data was shown graphically to help with information delivery and was then contrasted and examined.

RESULTS AND DISCUSSION

The results and discussion in study related influenced the amount of blades and blade rotor *twist* against *a speed* cut VAWT *Savonius* helix. *Cut in speed* is the minimum speed wind requires a turbine to spin and earn Power electricity (Sulaksono, 2019). The results of *the cut in speed* measurement data obtained can be seen in form Table 1 as follows :

Table 1 . Measurement Results *Cut in Speed*

Twist angle	*Cut in speed* (m/s)	
	Two blades	Three blades
90 °	2,15	1.81
180 °	1.99	1.51
270 °	1.99	1.55
360 °	1.92	2.45

According to the data, the correlation of blades and blade *twist* rotor as follows:

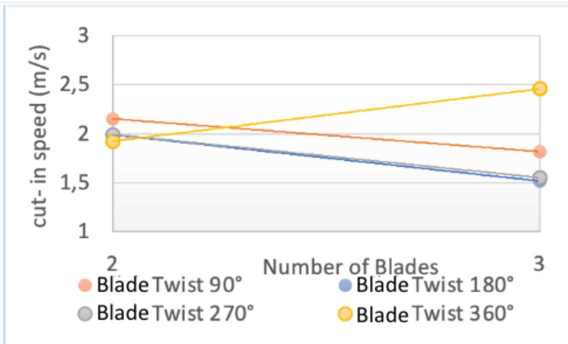

Figure 7. Chart Influence Amount Blade to *Cut in Speed*

Figure 8 shows the effect of the entire *blade* against *a speed* cut produced by the VAWT *Savonius* helix. The test shows that *the cut-in speed*s obtained for each number of *blades* 2 and 3 are different. Increase in the number of blades on the *twist bar* rotor 90° to 270° resulting in a decrease *in a cut in speed* obtained by the VAT *Savonius* helix but on the *twist bar* 360° increases when the number of blades increases on the VAWT *Savonius* helix.

The results showed that variations in the number of blades could affect *the cut in speed* obtained by wind turbines. Increasing the *twist bar of* the rotor also affects *the speed* cut produced by the VAWT *Savonius* helix. The wind turbine produces the lowest *cut in speed* at the number of blades 3, where *the speed cut* obtained from *the pitch* angle is 90° (1.81 m/s), 180° (1.51 m/s), 270° (1.55 m/s), and 360° (2.45 m /s).

According to the research data, the number of blade 3 is better than that of blade 2 when viewed from *the speed* cut. This is reinforced by Mahendra's research (2015) on a turbine with a total of 3 blades having a distance between one blade and another to the turbine blade shaft, which has a rift so that the flow can flow and hit the blades behind the shaft and will increase the moment force and reduce negative drag. On the blade so that the turbulence flow contained in the turbine is relatively small and *the cut-in speed* is low. Wisdom and Erwin's (2019) research shows that in the Savonius turbine using *a bach* rotor, it is found that blade 3 has the lowest *cut-in speed* compared to blades 2 and 4.

Figure 9 shows the influence of blade rotor *twists* against *a speed cut* produced by the VAWT *Savonius* helix. Testing shows that the cut-*in speed* obtained from the blade Rotor *twist* from 90° to 180° experienced a decline in *cut-in speed*. However, increasing the blade *twisted* rotor 180° to 360° experienced an increased *cut-in speed.* On variations amount blade two headed amount of 3 blades experienced decline *cut-in speed*, except for variations blade 360° *twist rotors*. Subtraction, *the cut in speed* that occurs on every variation blade *twist* rotor, fluctuates.

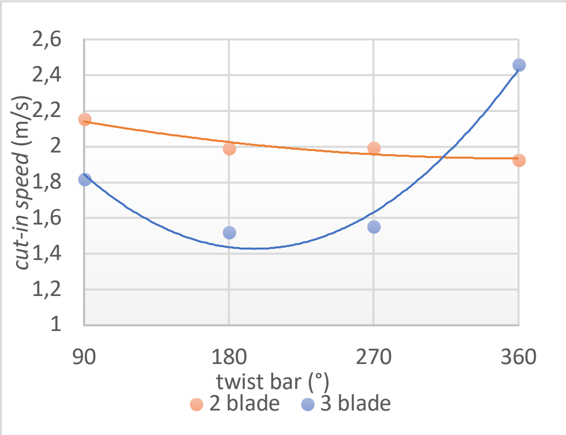

Figure 8. Chart Influence Blade Rotor *twist* against *Cut in Speed*.

The results showed that the variation of the *twisted blade of* the rotor could affect *the speed cut* obtained by the wind turbine. Increases the *twist bar* The rotor affects the decrease *in a speed* cut produced by a fluctuating horizontal wind turbine. The wind turbine produces the lowest *cut-in speed* at the *twist blade angle* rotor 180°, where *The cut-in speed* obtained for the number of blades is two blades (1.99 m/s) and three blades (1.51 m/s).

CONCLUSIONS AND SUGGESTIONS

Conclusion

Based on the results and discussion research described above, the blade and blade *twist* rotor variation can be influen*ced by cut-in speed* obtained by turbine wind. Increase the amount of blade influence to decline *cut in speed* produced by VAWT *Savonius* helix, where *cut-in speed* Lowest found in quantity blade 3 of 1.81 m/s on the blade 90° rotor *twist, 1.51 m/s on* blades 180° rotor *twist, 1.55 m/s on* blades 270° rotor *twist, and 2.45 m/s on the* blades 360° *twist rotors*. Increase blade influential rotor *twist* to *cut in speed* produced by VAWT *Savonius* helix in a manner fluctuating, where *cut-in speed* Lowest found on the blade 180° rotor *twist* of 1.99 m/s in total blade 2 and 1.51 m/s on the count blade 3.

Based on the exposure above _ it can be concluded that the *cut-in speed* lowest obtained _ from the variation amount blade and blade. *The twist* rotor is found in the VAWT *Savonius* helix with amount *blade* three and blade *twist* rotor 180°, where the cut-*in speed* obtained is 1.55m/s.

Suggestion

Furthermore, related turbine horizontal wind can be tested using a variation blade *twist* rotor with different angles, materials used, generator types, and various variations of others. It is necessary to be done to shed the light on the configuration and the best it can be used to tool renewable conversion *energy* VAWT *Savonius* appropriate helix condition wind in Indonesia in the future.

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