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THE EFFECT OF PITCH ANGLE VARIATION ON PERFORMANCE OF HYBRID DARRIEUS-SAVONIUS DUAL SHAFT VERTICAL WIND TURBINE

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All Vertical turbines use a fixed pitch angle; the determination of the pitch angle is very influential on the characteristics of a vertical wind turbine. In the initial stages of planning a Savonius Darrieus vertical turbine, an experiment was carried out to determine the best pitch angle, and the best pitch angle was 7 degrees. In its development, many designs have changed from the initial design, so it is necessary to carry out field experiments to get the best pitch angle. The purpose of this study is to recommend the best pitch angle for hybrid Savonius Darrieus dual shaft vertical wind turbines. That suit each wind characteristic with the variable performance tip speed ratio (TSR) also (λ), coefficient of performance (Cp), mechanical power and mechanical energy. Data is collected for 8 hours in real-time, using proximity sensors, anemometers, and an Arduino Mega to record and store data on a computer. The data collection interval at every 10 seconds. The data obtained is the RPM of the rotor and the RPM of the anemometer. The results of this study are the recommended pitch angle according to the wind speed, pitch angle of 5 degrees for 1 m/s wind speed, pitch angle of 8 degrees for 2 m/s a, and pitch angle of 8 degrees for 3 m/s wind speed.

Keywords: pitch angle, dual shaft vertical wind turbine, performance

1 INTRODUCTION

Vertical turbines typically use a fixed pitch angle, so research is needed to determine the best pitch angle for the wind velocity range planned for the wind turbine.

In the initial stages of designing a hybrid Savonius-Darrieus dual shaft vertical turbine, the best pitch angle was identified for the wind speed range of 1 m/s to 7 m/s (1). However, with the development of designs on wind turbine prototypes, it is necessary to re-investigate the determination of the best pitch angle for existing wind turbine prototypes. According to Mohammed MH the maximum pitch angle is three peaks in one cycle (2).

Based on wind speed data in various regions, Indonesia's wind energy speed range between 2.5 - 5.5 m/s at an altitude of 24 meters above ground level. With this speed, Indonesian wind energy resources are included in the low to medium class wind speed category. Overall, Indonesia's wind energy potential is estimated at 9,290 MW (3). Winds in the Indonesian region in general to the north of the equator blow from the Northwest to the Northeast. While in the south the equator blows from the Southwest to the Northwest. Except in southern Sumatra and Java, the wind blows from the east to the southeast.

Horizontal turbine with pitch angle at 15-degree angle shows the best performance (4). In Axial Six Blades Wind Turbine with wind speeds ranging from 2 to 5.6 m/s, the best pitch is at an angle of 80 degrees (5). Investigation of the turbine Savonius on pitch angles and the number of blades also affects the power produced, the number of blades 16 with an angle of 5 degrees is best to increase 4.5% from the reference conditions at wind velocity of 2.32 m/s (6). Numerical studies have also been carried out in investigating the effect of pitch angles on horizontal turbines (7). Steering fins have been investigated in previous studies and found significant performance improvements (8).

The novelty of this research is an investigation carried out on a Darrieus Savonius hybrid turbine with a Darrieus pitch angle that varies at low wind speeds of 1-2 m/s in order to obtain the optimum power that can be obtained.

2 RESEARCH METHODOLOGY

The pitch angle variations 4 to 9 degree were chosen based on Mohamed, MH (2) research, from this study some angles produce the best torque and power coefficient (Cp) for the S-1046 air foil profile at different TSRs, shown by Figure 6. Repetition occurs for the best angles that produce the highest torque and Cp, which ranges from angles 340o (-20o) to 20o, 100o to 135o, and 225o to 260o. In this study, the angle range of 340o (-20o) to 20o was chosen as the investigation angle because it is possible to design and manufacture at 0o and represent the plus (+) angle and minus angle (-) of the hybrid Savonius Darrieus dual shaft vertical turbine. S-1046 air foil also recommended by Wily Tjui (9).

They were then based on previous research (1, 10) in the design phase of this vertical hybrid wind turbine, which researched pitch 0-12o. At wind speeds of 2 to 7 m / s, an angle of 6o to 7o is the best. So in this study, the pitch angle variations are chosen 4o to 9o and are expected to get a pitch angle following the characteristics of the wind to improve the efficiency of the wind turbine.

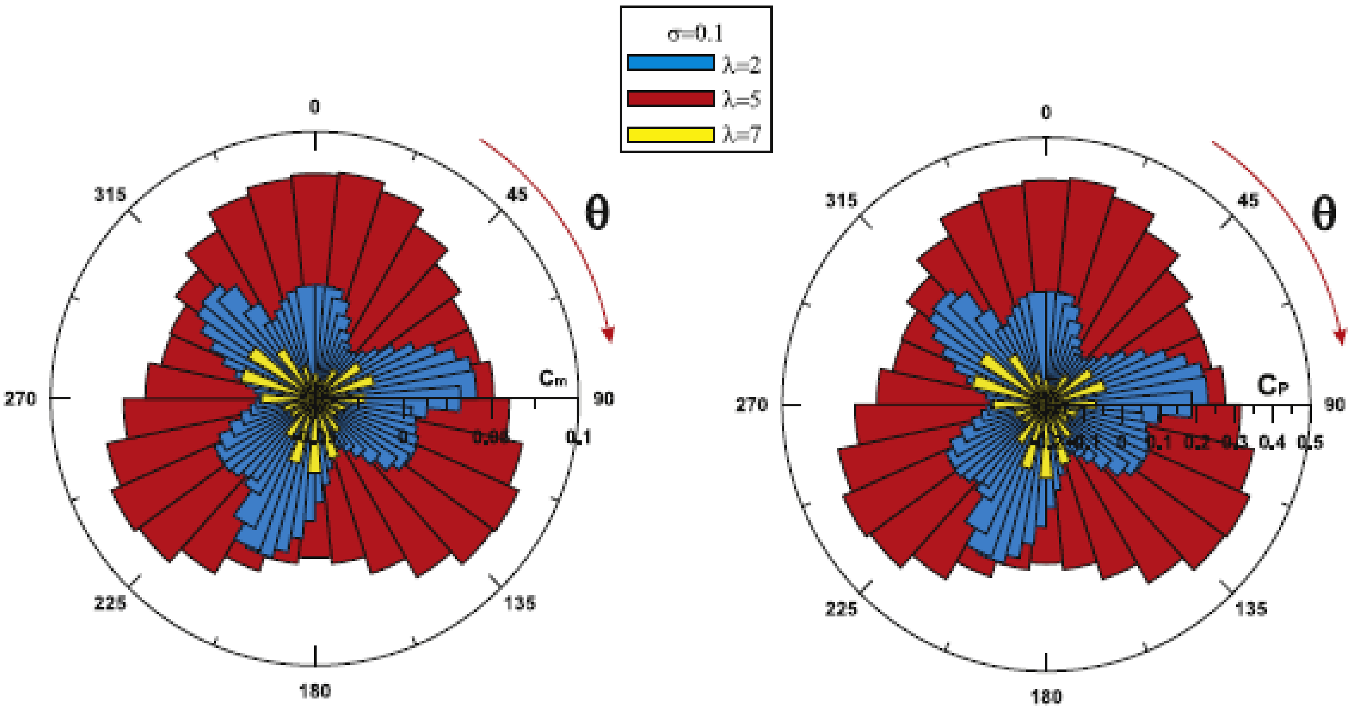


Figure 1. Pitch angle for Profile Air foil S-1046 with different TSR (2)

Figure 1. show a different pitch angle makes different TSR for air foil that used in this experiment. Experiments carried out at the pitch angle according to figure 1, on ours prototype hybrid Savonius Darrieus dual shaft vertical wind turbine for 8 hours running, then wind data processing following the IEC standard (11) to present TSR and CP data.

3 DATA AND ANALYSIS

From the experimental data obtained, the following results are achieved.

Table 1. data for pitch's 4º to 9º

Pitch 4º

Wind Speed (m/s)	Range time	TSR	CP	Power (watt)	Energy (Wh)	Wind Power (watt)	Wind Energy (Wh)
1	70	0.058	0.013	0.053	0.062	3.191	3.723
2	379.5	0.551	0.113	1.258	7.956	11.063	69.975
3	8.333	0.652	0.117	2.411	0.335	20.403	2.834

Pitch 5º

Wind Speed (m/s)	Range time	TSR	CP	Power (watt)	Energy (Wh)	Wind Power (watt)	Wind Energy (Wh)
1	80.000	0.143	0.072	0.298	0.398	3.322	4.429
2	349.167	0.761	0.291	3.464	20.158	11.813	68.742
3	23.667	0.883	0.253	5.526	2.180	22.617	8.921

Pitch 6º

Wind Speed (m/s)	Range time	TSR	CP	Power (watt)	Energy (Wh)	Wind Power (watt)	Wind Energy (Wh)
1	99.667	0.061	0.009	0.035	0.059	3.775	6.271
2	324.667	0.380	0.072	0.917	4.960	11.267	60.969
3	18.00	0.596	0.110	2.322	0.697	21.263	6.379

Pitch 7°

Wind Speed (m/s)	Range time	TSR	CP	Power (watt)	Energy (Wh)	Wind Power (watt)	Wind Energy (Wh)
1	69.000	0.203	0.069	0.291	0.335	4.098	4.712
2	370.333	0.532	0.159	1.980	12.219	11.182	69.020
3	20.167	0.861	0.297	7.371	2.478	24.570	8.258

Pitch 8°

Wind Speed (m/s)	Range time	TSR	CP	Power (watt)	Energy (Wh)	Wind Power (watt)	Wind Energy (Wh)
1	90.500	0.044	0.048	0.184	0.227	3.330	5.022
2	325.833	0.739	0.335	4.682	25.428	13.133	71.322
3	40.500	0.839	0.317	7.504	5.065	24.728	16.691

Pitch 9°

Wind Speed (m/s)	Range time	TSR	CP	Power (watt)	Energy (Wh)	Wind Power (watt)	Wind Energy (Wh)
1	90.500	0.044	0.033	0.125	0.203	3.608	5.833
2	325.833	0.739	0.079	0.907	5.297	10.585	61.837
3	40.500	0.839	0.040	0.806	0.103	21.976	2.808

Calculation data is processed into a graph to determine the pitch angle that can be recommended by the author for each wind characteristic.

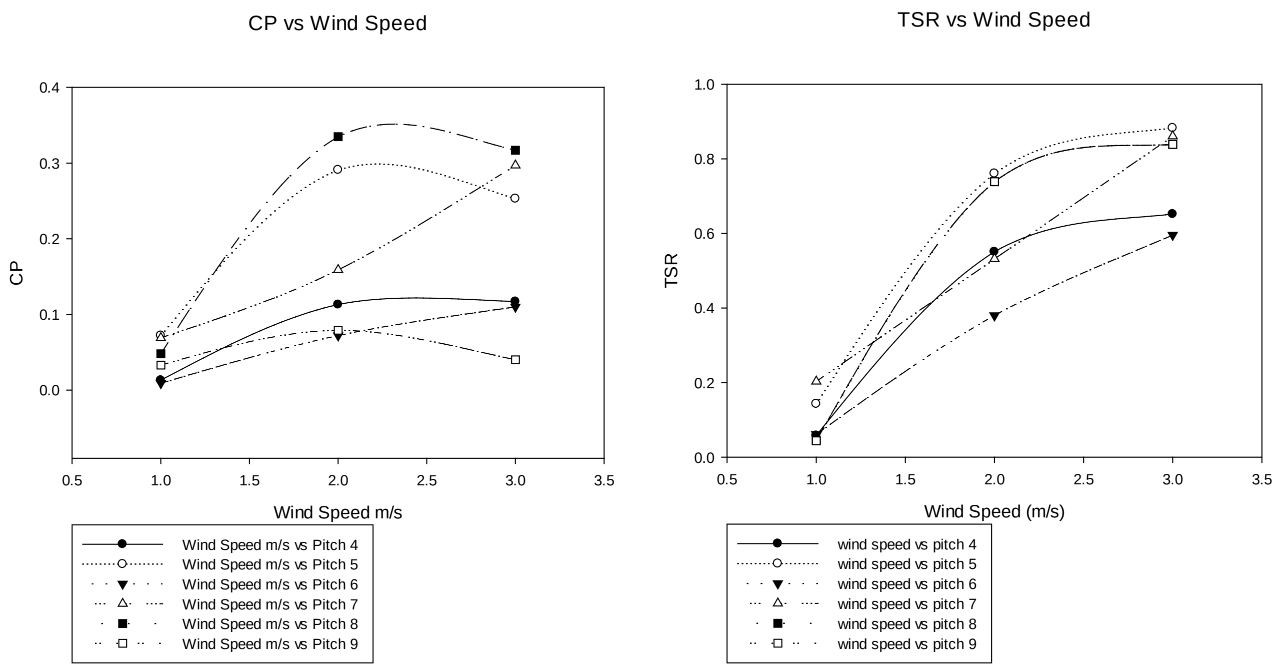
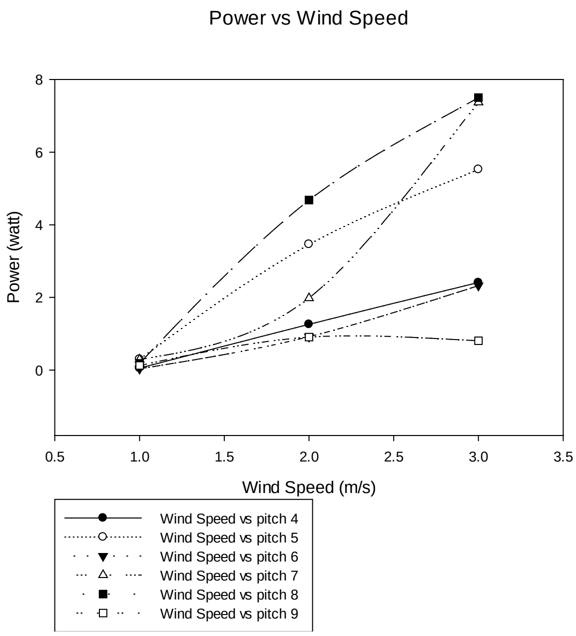
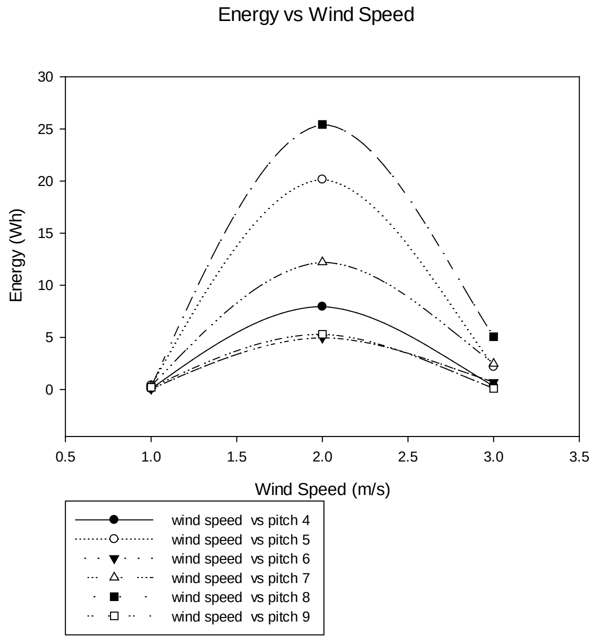


Figure 2. (CP vs Wind Speed) and (TSR and wind speed)



(A)



(B)

Figure 3. Mechanical Power vs Wind Speed (A) and Energy vs Wind Speed (B)

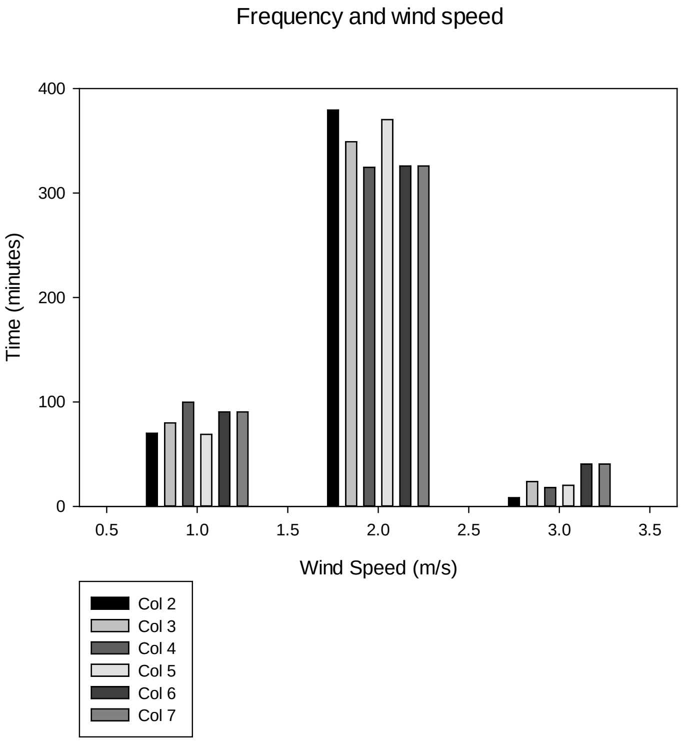


Figure 4. frequency and wind speed

4 PERFORMANCE ANALYSIS BASED ON VARIATIONS IN PITCH ANGLES

This section will discuss the overall performance of the turbine-based on variations in pitch angles regarding the performance variables considered in the previous chapter.

Based on Figure 1, the graph TSR (Tips Speed Ratio) and wind speed, the best TSR results obtained at wind speed 1 m/s is a pitch angle of 7^o with TSR = 0.203, at wind speed 2 m/s is a pitch angle of 5^o with TSR = 0.739, and at wind speed, 3 m/s is a pitch angle of 5^o with TSR = 0.839.

The efficiency of Sultan Wind Turbine v.4.5 based on Figure 1, which is a Cp graph and wind speed obtained the best Cp results at a wind speed of 1 m / s, there was a small difference between pitch angle of 5^o with Cp = 0.072 and a pitch angle of 7o with Cp = 0.069, at speed wind 2 m / s is a pitch angle of 8^o with Cp = 0.335. At wind speed, 3 m / s is a pitch angle of 8^o with Cp = 0.317.

Turbine mechanical power based on Figure 3.A is a graph of mechanical power and wind speed obtained the best mechanical power results at wind speed 1 m / s. A pitch angle of 5^o, It can produce power = 0.298 Watt, at wind speed 2 m / s is a pitch angle of 8º with power = 4.682 Watt, and at wind speeds of 3 m / s is a pitch angle of 8º with power = 7.504 Watt.

Mechanical turbine energy based on Figure 3.B is a graph of mechanical energy and wind speed obtained the best mechanical energy results at wind speed 1 m / s. A pitch angle of 5º with energy = 0.398 Wh, at wind speed 2 m / s is a pitch angle of 8º with energy = 25.4428 Wh, and at wind speeds of 3 m / s is an 8º pitch angle with energy = 5,065 Wh.

In addition to the variables mentioned, another thing that needs to be analyzed in the performance of wind turbines is the potential of wind energy. Based on Figure 4.16, the wind with the highest frequency of time is a wind with a speed of 2 m / s. Also based on Figure 4.15 is the most significant wind energy potential, the most significant mechanical energy produced by this vertical hybrid wind turbine is at a wind speed of 2 m / s. Therefore, turbines must be able to optimize the potential of wind energy at these wind speeds.

From the performance analysis, as described, it can also be seen the shortcomings of this wind turbine. The disadvantages are as follows.

1) The power produced is small; the most significant power generated by the turbine is only 7.504 Watt.

2) At each speed has the highest efficiency with different pitch angles. Therefore, it is necessary to do further research on angle regulators based on the ongoing wind speed.

The following are the core results of the research that the author conducted based on data obtained during the study and following the purpose of the study which is to determine the best pitch angle on the performance of the turbine, which corresponds to each wind characteristic, shown in the table below this.

Table 2. Pitch angle recommendation

Wind Speed (m/s)	Pitch	TSR	CP	Power (watt)	Energy (Wh)
1	5	0.143	0.072	0.298	0.398
2	8	0.739	0.335	4.682	25.428
3	8	0.839	0.317	7.504	5.065

5 CONCLUSIONS

It is concluded that the recommended pitch angle matches for each wind characteristic, i.e., at 1 m / s velocity is a 5º pitch angle, a velocity of 2 m / s is the pitch angle of 8º. The speed of 3m / s is the pitch angle of 8º, and based on most frequent of wind speed, it chooses pitch angle of 8º of fin for low-speed wind. further testing of the parameters of the higher wind speed is required at least up to 7 m / s.

6 ACKNOWLEDGEMENTS

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