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Balancing and Alignment Analysis of Vertical Wind Turbine Helix Type and Savonius Type

A. Finali*, P.B.W. Wardhana, R.E.P. Utomo, IGN A.S.P.D. Yudha

Department of Mechanical Engineering, Politeknik Negeri Banyuwangi, Jalan Raya Jember KM. 13, Banyuwangi, 68461, Indonesia
**Corresponding author email: asmar@poliwangi.ac.id*

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ABSTRACT

Electrical energy is one of the basic needs that is very important in life, in addition to the physiological development of living things, electricity is also an input for various efforts or activities in order to produce something for survival. Therefore, renewable energy that is more environmentally friendly and an inexhaustible source of energy is needed, namely wind energy. This power generator is called a wind turbine with a vertical shaft. This turbine converts wind energy into mechanical and electrical. In order to obtain a turbine design with high efficiency. It is also necessary to balance and align each component frame attached to the turbine rotor to produce a perfect/ideal rotation, so as to minimize the occurrence of vibrations caused by the imbalance. the results of calculations with the analytical method on Darrius Helix type obtained value = 0.125 Newton, and = 0.175 Newton, and the value of the angle = 63.43490. Alignment testing is carried out to determine the value of the misalignment between one blade with another blade. The results of the balancing test with the blade ballast obtained additional value, the blade D was 70 grams and the results from the plate addition test were obtained according to the calculation of the analytical method but also less than the maximum requiring additional load on the blade body to get blade A = 12 grams, blade B = 0, blade C = 40 grams, and a spoon D = 90 grams. For the results and discussion of the balancing and alignment method on the savonius type using the static balancing and alignment method using a dial indicator, the values obtained are in the fields A and B, the addition of mass is 59.007 grams and 59.007 grams with angles A and B 11.88°, and the value of misalignment deviation in the A, B and center planes is A: 4 mm, B: 0.04 mm, middle: 0.52 mm, while the shaft alignment value is 0 because the value of the alignment of the shafts is the same or parallel.

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Keywords: Darrius Helix; Savonius; Balancing; Alignment.

1. Introduction

Utilization of electrical energy as a basic human need, but electricity in Indonesia has not been fulfilled like in corner areas. According to data from the Indonesian Energy *Outlook* 2019 book from the Ministry of Energy and Mineral Resources, no less than 86% of the world's energy now comes from mining fuel [1], while the world's demand for energy is increasing. That's why experts are looking for alternatives to energy sources that can be used as electrical energy.

The most of Banyuwangi Regency territory is mountainous. Many people who live in the highlands do not have electricity from the government. Due to the inaccessibility of electrical installations that are usually obtained from PLN. So we need renewable electrical energy that is more environmentally friendly. Electricity is one of the most significant and important needs for the continuity of human life, in addition to the physiology of living things, electricity is an input for various activities to produce something to support life's needs [2].

One of the renewable energies in Indonesia is wind energy. Wind energy is energy that is environmentally friendly, energy that is easily obtained and renewed so that it has the potential to be developed. Wind energy potential in Indonesian regions generally has a low speed, which is between 3 m/s to 7 m/s, so that the type of use of vertical type wind turbines is possible to be very suitable [2]. Vertical/upright axis wind turbines (or TASV) have a main rotor shaft with a perpendicular model. The advantage of this arrangement is that the turbine does not need to be pointed into the wind to be always effective. VAWT is able to accept wind from all directions.

Research on vertical type wind turbines needs to be carried out on the turbine rotor to produce a perfect/ideal rotation, so as to minimize the occurrence of vibrations caused by this imbalance. It is hoped that the results of this research will become one of the references for academia and the electricity industry that use renewable energy [3].

The formulation of the problem in this research is: How to plan the testing of balancing and alignment of wind turbines with vertical axis types of helix and savonius and what are the mechanisms and systems for testing balancing and alignment on vertical axis wind turbines of the helix and savonius types .

This study only calculates the balancing and alignment values of the Helix and Savonius wind turbines , namely the Technology Readiness Level (TKT) 3. The research was conducted on a 4-blade turbine. In order to know how to plan and test balancing and alignment on vertical wind turbines of the helix and savonius types, to know and understand the mechanism and testing system for balancing and alignment on vertical axis wind turbines of the helix and savonius types.

The benefits of this research are the analytical results of the turbine blade balancing and alignment test planning. Vertical wind turbine blade balancing mechanism in Indonesia.

Vertical Axis Wind Turbine (VAWT), included in a wind turbine that has a shaft with a vertical axis can be seen in Figure 1. This type of turbine receives wind from various directions. Because the blade surrounds the shaft. This vertical shaft wind turbine does not require high construction. Vertical wind turbines also have standard models according to their shape, such as savonius, darrius, cross-flow and giromill [4,5].

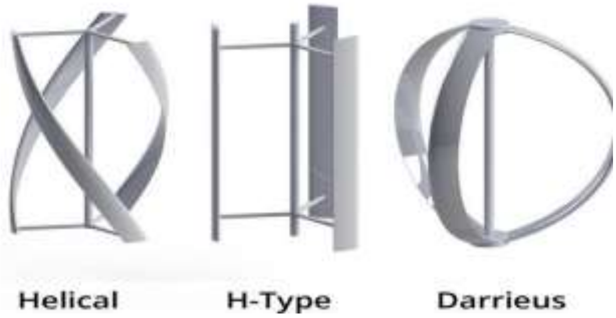

Figure 1. Vertical Wind Turbine Type

Helical H-rotor, the H-rotor was modified into another variant in which the blades are twisted along the perimeter to form a helical shape as shown in figure 1. Surprisingly, this modification was intended to be a water turbine since it was invented by, Professor AM Gorlov of Northeastern University, an expert in hydropower [4] . This invention was granted US Patent no. 5,451,137 & 5,451,138 of September 19, 1995. Although the turbine was originally designed as a water turbine, the disclosed patent states that it can be used for hydro-pneumatic, hydro, wind and wave power systems.

The helical H-rotor improves the performance of the H-rotor by uniformly distributing the blade profile along the rotor perimeter, and thus, making the swept area and blade section constant to the wind in all instances of turbine rotation. Therefore, the rotor torque fluctuations are significantly reduced when the blade shape includes a full 360 rotation. Benefits of having regular torque include better regulation of power output and reduced cyclic stress on the drivetrain. In addition, the noise is reduced and a slightly higher effective chord is obtained. Currently, the Helix design is gaining popularity not only for its better performance, but also for its aesthetic value, where a modern elegant design harmonizes the elements in the space, for more details can be seen in Figure 2.

Figure 2. Helix Wind Turbine

Savonius windmill with a different number of blades, where the Savonius windmill has 3 blades, has a mechanical efficiency of 76%. Another research is the variation of the number of blades 2, 3 and 4 in the Savonius type L turbine, the best 3 blades and the lowest 4 blades efficiency is obtained. Another study on the Savonius windmill, 2 and 3 blade transformations and the use of Guide Wings, obtained results when using 2 blades with optimal efficiency. Another study is the transformation of the curved shape of the L-type Savonius turbine blades , the result is a 20^{0} curvature with optimal efficiency. The study of the Savonius turbine with low wind speed was also observed, it was found that the efficiency of the Savonius turbine was in the efficiency range of 4.8% to 14.5%. Research on the Savonius turbine that focuses on blades has been carried out, specifically studying variations in the distance of the turbine blades of 1, 2 and 3 cm where the distance is 1 cm for optimal performance. Another study focused on the effect of blade curvature on the performance of the Savonius windmill , the results of the study showed that the blade curvature also affected the performance of the Savonius windmill [6].

Savonius turbines combining with other turbines or other sources of power generation from the Savonius turbine , are hybrids of Savonius and Darrieus, are also being studied. Another study is between a hybrid of a Savonius turbine (Figure 3) and a solar cell to generate electricity [7].

Figure 3. Savonius Wind Turbine

To determine the number of blades itself refers to several studies that discuss the effect of the number of blades on the vertical axis of the Darrieus Helix . The number of blades itself is very efficient and can produce very large power, which is 4 blades. The following are the results of research in one of the studies as follows:

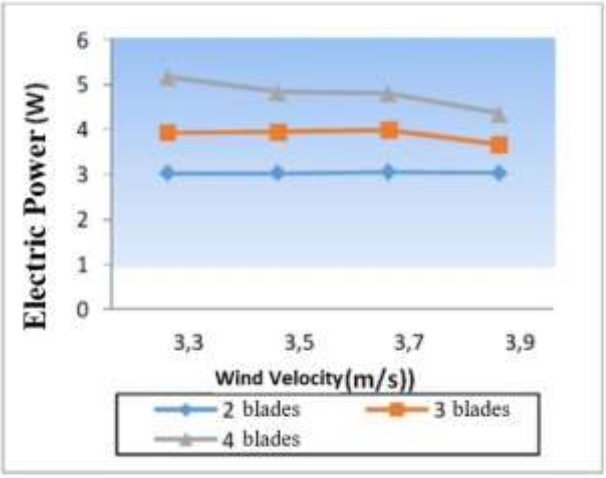

Figure 4. Graph of Comparison of the Number of Turbine Blades

Figure 4. shows the graph, that is, at 2 units and 3 units of blades, the wind speed does not significantly affect the results of electric power (Fachrudin, 2018). At blades numbered 2 and 3, the difference in the electrical power generated is not significant. With a total of 4 blades, there is a significant difference in the electrical power generated at each wind speed. The greatest electric power is obtained at a wind speed of 3.3 m/s of 5.165875 W and decreases at a wind speed of 3.5 m/s, 3.7 m/s and the smallest electric power at a wind speed of 3.9 m/s that is equal to 4.3559 W.

Analytical Method, The equations which can be applied to an analytical solution concerning the balance of a system of rotating masses, are derived as follows [6].

a) For the balance of horizontal forces:

$$\sum WR\cos\theta = 0 \qquad (1)$$

b) For the balance of vertical forces:

$$\sum WR\sin\theta = 0 \qquad (2)$$

.

2. Methodology of Research

The balancing and alignment testing of the Helix and Savonius wind turbine blades with the parameters in Table 1 following :

Table 1. Constant Variable for Helix and Savonius turbines

Turbine Type	**Shaft diameter**	**Shaft Materials**	**Blade Materials**	**Blade Diameter**
Helix	15.8mm	ST41	PLA	1 m
Savonius	15.8mm	ST41	PLA	1 m

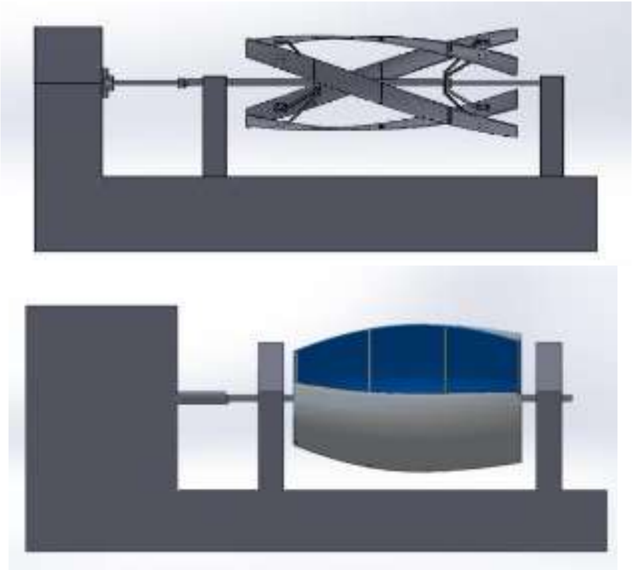

Figure 5. Turbine Blade Test Design

Meanwhile, what is analyzed or the response to be shown is the comparison of the deviation between the blades, as shown in Figure 5, with the blades rotated manually on the test equipment.

The flowchart in this study is shown in Figure **6**.

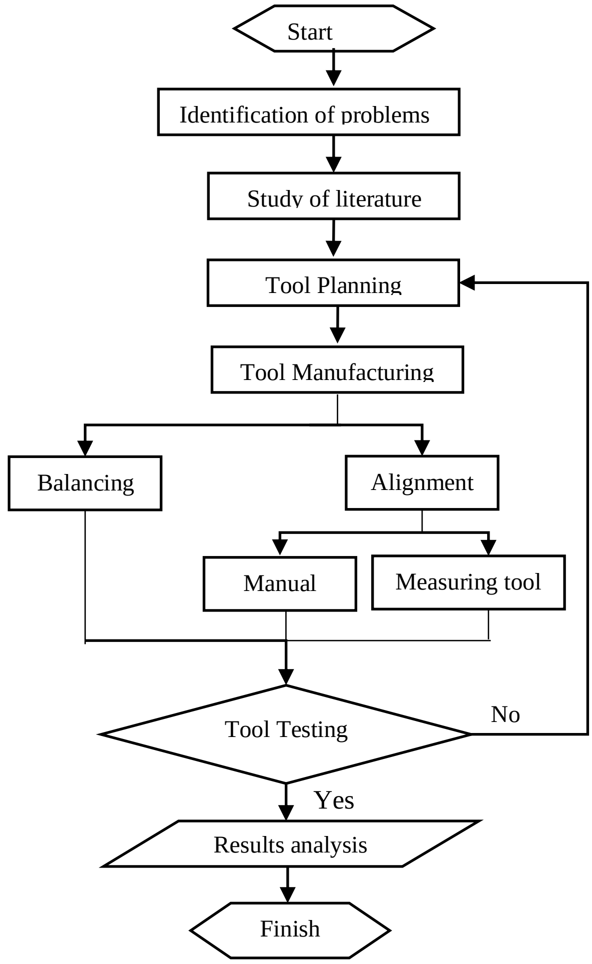

Figure 6. Research Flowchart.

After researching, data and developing concepts, planning mechanisms for comparison of balancing and alignment measurements between blades and between types of turbines can be carried out. Planning is the first step, so it must be done carefully, and the concept must be balanced with careful calculations so that the turbine is balanced and operates optimally. Here’s the plan:

1. Balancing planning .
2. Alignment planning [7].

3. Result and Discussion

The weight of the turbine blade and cross section are weighed to determine the weight per section. To find out the cross-sectional weight and blade weight, weighing is carried out using a digital scale, the results are obtained in Table 2 and Table 3 under:

Table 2. Helix Turbine Blade Weight Data

No	Blade	Top View	Lower Cross
A	1.185 kgs	0.365 kg	0.365 kg
B	1.185 kgs	0.375 kg	0.365 kg
C	1.215 kgs	0.355 kg	0.365 kg
D	1.195 kgs	0.375 kg	0.375 kg

To get the value of the weight on the blade can be seen in Figure 7, the unit is converted into Newtons by multiplying the acceleration due to gravity.

A = 1.185 x 9.8 = 11.613 N
B = 1.185 x 9.8 = 11.613 N
C = 1.215 x 9.8 = 11.907 N
D = 1.195 x 9.8 = 11.711 N

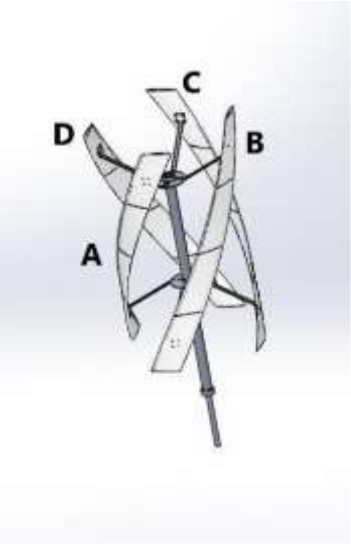

Figure 7. Blade Weighing

Table 3 . *Savonius* turbine blade weight data

No	Blade
W1	1526 grams
W2	1604 grams

Calculation of Center of Weight (R), Center of gravity is the midpoint on the part of the blade which is a balancing point which will be added and subtracted during the test. The center of gravity (R) on the turbine blade refers to the design of the blade in the simulated solidwork software obtained X = 349.27 mm and Y = 335.82 mm. For more details can be seen in Table 4 and Table 5.

Table 4. *Helix* Turbine overall yield data

No	W	R	ϴ	A	COS	sin
W1	11,613	484,5	45°	50	0,707	0,707
W2	11,613	484,5	135°	50	0,707	0,707
W3	11,711	484,5	225°	50	0,707	0,707
WA	0,125	500	63°	0	0,707	
WB	0,174	500	63°	86		

The value of WR cos θ can be immediately known by multiplying:

WR cos θ = W x R x COS θ
= 11.613 N x 484.5 x 0.707
= 3977.93444

And the value of WR sin θ can be found by multiplying:

WR sin θ = W x R x SIN θ
= 11.613 N x 484.5 x 0.707
= 3977.93444

Table 5. *Helix* Turbine overall yield data (continued)

No	WR cos ϴ	WR sin ϴ	WRa cos ϴ	WRa sin ϴ
W1	397,793,444	397,793,444	198,896,722	198,896,722
W2	-397,793,444	397,793,444	-198,896,722	198,896,722
W3	-4,078,641,641	-4,078,641,64	-203,932,082	-203,932,082
W4	4,011,503,507	-4,011,503,507	2,005,751,753	-2,005,751,753
WA	2,810,433,516	5,620,867,033	0	0
WB	3,903,379,884	7,806,759,767	33,569,067	67,138,134
	∑=0	∑=0	∑=0	∑=0
	(Static Balanced)		Dynamic balance	

The results of measuring the distance of the blade to the center point, measuring the distance of the blade to the center point is measured using a meter, which obtains a slightly different distance value due to several factors, namely the slightly changed shape of the blade and also an imperfect fabrication process. The measurement results are shown in Figure 8 and Table 6 as follows:

Figure 8. Measurement between blades

Table 6. The results of measuring the distance between the *Helix turbine blades*

Blade	Distance Between Blades	
	On	Lower
AB	58.5cm	61cm
BC	59 cm	60cm
CD	61cm	61cm
DA	61cm	60.5cm

Balancing test (Figure 9), namely the position of the ballast placed on the body of the blade and also the angle is not supported by the calculation, the results of the ballast obtained are 70 grams and the position of the blade after being rotated can change randomly.

Figure 9. Balancing test with ballast on Helix blades

Determination of the center of gravity (R) on the *Savonius turbine blade* , shown in Figure 10.

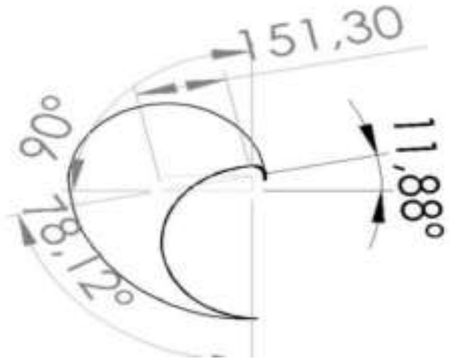

Figure 10. Determination of center of gravity with Software

The center of gravity (R) on the turbine blade refers to the design of the blade in the simulated solidwork software obtained X = 148.06 mm and Z = 31.16 mm.

$R = \sqrt{(148.06^2 + 31.16^2)}$

$R = 151.30$ mm

$\theta_{w1} = 11.88^o$

$\theta_{w2} = \theta_{w1} + 180^o = 191.88^o$

$WR_{\cos\theta} = W \times R \times COS\ \theta$

$= 1526 \times 151.3 \times 0.978581$

$= 225938.4778$

$WR_{\sin\theta} = W \times R \times SIN\ \theta$

= 1526 x 151.3 x 0.205863
= 47530.34139

The value of WRa cosθ can be immediately known by direct multiplication:

WRa cos θ = W x R xax COS θ
= 1.526 x 151.3 x 450 x 0.978581
= 101672315

The WRa sin θ value can be found by multiplying:

WRa sin θ = W x R xax SIN θ
= 1.526 x 151.3 x 450 x 0.205863
= 21388653.63

The value of WR cosθ and WR sinθ in the Savonius turbine can be obtained by adding up the columns of the respective values and the sum of the columns which must be zero.

$WBRBaB$ cos θ = 0
-101,672,315 – 106,869,196.1+ 0 + Σ = 0
Σ = 0 – 101,672,315 + 106,869,196.1
= 5,196,881.1

$WBRBaB$ sin θ = 0
21,388,653.63 – (-22,481,913.77) + Σ = 0
Σ = 0 - 21388653.63 +22481913.77
= 1,093,260.1

Savonius turbine can be seen in table 7 below.

Table 7. Savonius turbine overall yield data

NO	W	*R*	*θ*	*a*	*C O S θ*	*SIN θ*
W *1*	1526	151.3	11.88	450	0.97858	0.205863
W2	1604	151.3	191.9	450	-0.97858	-0.20586
WA	59,007	100	11.88	0	0.978	0.20586
WB	59,007	100	11.88	900	-0.97	-0.2059

KNOW	W *R C O S θ*	W *R WITHOUT θ*	W *R and C O S θ*	W *R and SIN θ*
W *1*	225938.47	47,530.34	101672315	21388653.6
W2	-237487.1	-49959.8	-1.07E+08	-22481914
WA	5774.31	1214.73	0	0
WB	5774.31	1214.73	5196881.1	1093260.15

Alignment stage, namely using a horizontal support device, namely bearing and the method used is the waterpass method and dial indicators at each point that will be aligned as shown in Figure 11 following:

Figure 11. *Savonius* turbine blade *alignment* test

In shaft *alignment* using the dial indicator method with 2 locations, namely points A and B. The first step is to measure the pipe shaft using a waterpass after that attach the dial indicator to the pedestal and setting the dial indicator, setting the dial indicator aims to determine the point where the shaft will be measured . In measuring the dial indicator on shaft A, a dial value of 0.33 mm is produced, while on shaft B, a dial value of 0.33 mm is produced.

4. Conclusion

Based on the *balancing* and *alignment tests* on the Wind Turbine rotor that have been described, it can be concluded as a whole that planning from the results of calculations using the analytical method for the *Helix turbine*, the values for WA = 0.125 N, and W_B = 0.175 N, as well as the angle values θ_A =

63.4349°, and $\theta_B = 63.4349°$. Balancing test planning using the analytical method for the Savonius turbine obtained values WA = 59.007 gram = 0.579 N and WB = 59.007 gram = and also $\theta_A = 11.88°$ and $\theta_B = 11.88°$. Alignment testing is carried out only to determine the value of misalignment between one blade and another. The results of the balancing test with blade weights are the additional value obtained at blade D is 70 grams.

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