Prototype design of wind power water pump for irrigation

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Abstract. The main objective of this research was to produce a prototype of a simple water pump using a TSAV (vertical axis wind turbine) wind turbine as a prime mover and to analyze the relationship between wind speed and speed of windmill spin with the dependent variable in the form of water flow from the pump. The study used experimental and design methods. The test results obtained a wind speed of 3.6 m / s in an average windmill rotation of 5.6 rpm. Based on ANOVA test, the wind speed in the morning, afternoon, evening, and night had a significant difference. The highest wind speed occurred during the day at 4.3 m / s while the lowest wind speed occurred at night at 2.2 m / s. Water discharge generated by the pump was 2.0347 liters/minute with an efficiency of 89.7% pump. The results of the analysis showed that wind speed, windmill spin, and water discharge could change linearly. The higher the wind speed, the greater the number of spinning windmills, and the more water discharge produced. Therefore, the results of testing the pump can work well and has the potential to be developed in the region with the existing wind speed.

1. Introduction
Merauke Regency is one of Indonesia's agricultural centers. Wide and flat land gives the potential to be developed in various types of food and horticultural commodities. But in its development, agriculture in Merauke Regency only relies on rainwater and swamps to meet production needs. The regional government is developing the construction of long storage and reservoirs on agricultural land to collect rainwater for irrigation. However, agricultural land is located higher than long water storages, reservoirs, and swamps, so it requires a pump to lead water to the farming fields.

The pumps used by farmers are generally fuelled by gasoline and diesel (conventional energy) [1]. Conventional energy is currently diminishing, scarcity often occurs, and the price is high. High fuel prices make it difficult for farmers because it causes high production costs. Thus, farmers need the right technological solutions to reduce production costs. Appropriate technologies such as wind power pumps, hydropower pumps, and solar power pumps are types of pumps that do not require engines and fuel [2].

The wind is a non-conventional energy source. The use of wind energy in Merauke Regency has not been utilized optimally. The flat topography and located on the coast cause the wind to blow unhindered. The average wind speed in Merauke Regency in 2013 was 13 knots or 6.69 m / s [3]. According to [4], the minimum wind speed needed to turn on the artificial windmill is 3.9 m / s. This shows that wind energy in this area has the potential to be developed further.
The purpose of this study is to produce a prototype of a simple water pump using a TSAV (vertical axis wind turbine) wind turbine as a prime mover and to analyze the relationship between wind speed and wind speed with a dependent variable in the form of water discharge from the pump.

2. Methods

2.1. Location and time of research
The study was conducted in the field area of the Agricultural Engineering Laboratory of Musamus University and lasted for four months from March to June 2015.

2.2. Design of tool
The design of the wind power water pump made can be seen in Figure 1. The manufacturing of the tool started with the process of making pump components, windmills, and ends with the tool assembly process. The type of windmill made was a vertical axis wind turbine (TSAV). The diameter of the Ferris wheel was 200 cm, and 8 blades were made. Ferris wheel was made into rectangular, made of steel. Tower height was 150 cm. The pump made was a piston pump type water from PVC pipe. The pump tube consisted of three main components, namely the pump tube, the valve, and the piston. The pump tube was 45 cm long and 2 inches in diameter. One side of the tip was cut in such a way that it was seen the U-shaped from side with a hemisphere measuring 15 cm long and 3 cm wide. Pump suction hose was inserted into the water source with a depth between the surface of the water with the pump that was 2 m.

![Figure 1. The prototype of Wind Power Water Pump](image)

2.3. Tool testing and observation
The parameters measured were wind speed, the number of windmill turns, and water discharge generated by the pump. Observations were made for seven consecutive days during testing. Every day four inspections were conducted, particularly at 08:00, 12:00, 16:00, and 22:00. Each observation was carried out three times every 60 seconds for each round.
2.3.1 Wind Speed (m / s) and Number of Windmills Spin (Rpm). Wind speed was determined based on the results of measurements using an anemometer. The number of windmill spin was observed by giving the cursor a needle and counting it manually. The measure of wind speed and rotation of the wheel was done at the same time. The wind speed and windmill rotation tests were carried out twice, that were pump testing with load and without load.

2.3.2 Water discharge (litters/minutes). Water discharge that was generated by the pump for 60 seconds was collected in a bucket and measured using a measuring cup.

2.3.3 Data analysis. At certain air densities and wind speeds, winds had the following dynamic wind pressure:

\[ q = \frac{1}{2} \rho v^2 \]

Where: 
- \( q \) = Wind dynamic pressure (kg / s.m2)
- \( v \) = wind speed (m / s)
- \( \rho \) = air density (kg / m3)

Dynamic wind pressure that hit a certain sweep area will produce wind force. Thus, the wind force was obtained from the multiplication between dynamic wind pressure and sweep area as follows:

\[ F = qA \]

Where: 
- \( F \) = wind force (kg / s)
- \( A \) = sweep area (m2)

So, the wind power (\( P_{\text{wind}} \)) was the multiplication between the force and the wind speed [5].

\[ P_{\text{wind}} = Fv \]

3. Results and discussions

3.1 Windmills and piston pumps
The prototype of the water pump of wind power design can be seen in Figure 1. Windmills were made of iron and zinc plates. The windmill span when the wind that blows, hit the blade of the windmill. The blades turned the dynamic motion of the wind into the rotation of the mill. The rotational motion of the pinwheel was converted into a transitional motion (back and forth) by the crankshaft resulting in pump action. The backward movement of the piston caused water got sucked into the pump tube through the suction valve (suction step). After the backward motion reached its peak point, the piston motion changed the direction to a forward motion resulting in the water being pushed out through the exhaust valve (the exhaust step). During the suction step, the pump suction valve opened automatically while the exhaust valve is closed. This happened oppositely in the discard step process. The mathematical volume of each pump was 2268.9 cm3. The windmill had a dimension of 0.9 m high blade and diameter of 2.7 m. The area of wind stroke against the windmill was 2.4 m2.

3.2 Wind speed
Anova test results of a single factor of wind speed data obtained an F value of 26.46384 with a P-value of 2.64E-14 and an F table with df: (0.05, 3, 203) of 2.648432. F value> F table then there was a significant difference in the average wind speed each time. Various wind speeds in the morning, afternoon, evening, and night were shown in Figure 2. The highest wind speed occurred during the daytime of 4.3 m / s, while the lowest wind speed occurred at night of 2.2 m / s. The high wind speed
during the day is caused by hot weather. The sun’s heat causes the atmospheric air to expand quickly, and its density to be small so that the air will rise. The air void below will be filled with air with a large density. At night the wind speed becomes low because there is no heating of the atmospheric air. As stated by [6] that the wind movement is caused by differences in air pressure in certain areas.

![Figure 2. The Relationship between Wind Velocity and Time](image)

3.3 Wind power and pump discharge

The results of testing wind speed, number of windmills spin, and the volume of water is obtained by the average values are presented in Table 1. The results showed that the average value of wind speed at the test location was 3.6 m / s. The average value of the waterwheel rotation was 5.6 rpm, and the average water volume produced by the pump was 2034.7 cm3. From these data, wind power (P\text{wind}) and pump discharge can be mathematically determined. The results of wind dynamic pressure calculation that hit the windmill blades gained wind power of 67,212 kg.m / s.

| No | Windmill Spin (Rpm) | Wind Velocity (m/s) | Water Volume(cm³) |
|----|---------------------|---------------------|-------------------|
| 1  | 4.00                | 2.37                | 1285.56           |
| 2  | 4.83                | 3.11                | 1879.17           |
| 3  | 5.08                | 3.34                | 1733.33           |
| 4  | 5.13                | 3.11                | 1896.25           |
| 5  | 5.44                | 3.38                | 2005.56           |
| 6  | 6.22                | 2.98                | 2311.11           |
| 7  | 6.27                | 4.79                | 2263.64           |
| 8  | 6.33                | 4.77                | 2266.67           |
| 9  | 7.08                | 4.15                | 2670.83           |
|    | **Average**        | **3.6**             | **2034.7**        |

Discharge (Q\text{pump}) is defined as the amount of volume of water produced by the pump (Vpompa) per unit time (t). The average volume of water produced by the pump was 2034.7 cm3 for one minute. Then the discharge generated by the pump was 2034.7 cm³ / minute or 2.0347 liters/minute.

The test result data in Table 1 shows the correlation between wind speed and windmill rotation and the correlation between the number of windmills spin and the volume of water produced. The correlation between wind speed and windmill rotation can be seen in Figure 3. Figure 3 shows that the higher the wind speed (v) that hits the windmill, the greater the spinning wheel (\omega) produced. So, it
can be concluded that the spinning wheel is directly proportional to the wind speed. This is the same as expressed that the flow of wind will move the rotor (blades) which causes the rotor to rotate in harmony with the blowing wind. Mathematically the relationship of wind speed and windmill rotation can be formulated as follows: \( y = 0.8685x + 2.5125 \) where \( y \) = windmill rotation (Rpm) and \( x \) = wind speed (m/s).

**Figure 3.** Correlation between wind speed and windmill rotation

The correlation between windmill rotation and the volume produced by the pump can be seen in Figure 4. In Figure 4 indicates the higher the windmill spin number, the greater the volume of water produced by the pump. Mathematically, the relationship of the spinning wheel with the volume produced by the pump can be formulated as follows: \( y = 411.97x - 272.22 \) and a coefficient of determination of 95.7%.

**Figure 4.** Correlation between windmill rotation and the volume generated by the pump

Based on Figures 3 and 4 the volume of water produced by the pump and the number of spinning wheels will change linearly with the wind speed. The higher the wind speed, the greater the number of spinning wheels and water discharges produced.
3.4 Pump efficiency
Pump efficiency is a comparison of the volume of water produced by the pump ($V_{\text{Pump}}$) with the mathematical volume of the pump ($V_{\text{mathematical}}$). The volume of water produced by the pump in this study was 2034.7 cm$^3$, and the accurate volume of the pump was 2268.9 cm$^3$, so the efficiency value was 89.7%. This means that the pump has a low leakage rate.

4. Conclusion
According to the results of research and discussion that has been described, it can be concluded that windmills are designed to spin well. An average wind speed of 3.6 m / s produces a windmill spin of 5.6 rpm. A piston-type water pump can move water with a pump head of 2 m. The discharge of water produced by the pump is 2,0347 liters/minute with a pump efficiency of 89.7%. The discharge generated by the pump changes linearly with changes in the windmill spin and wind speed.

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