Effect of Tilt Angle on Archimedes Screw Pump Driven by Savonius Helical Windmill on Water Debit

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A B S T R A C T

One of the most abundant sources of renewable energy is wind energy. Indonesia has potential for low-speed wind because it is dominated by low-lying areas. Wind turbines consist of two types, namely horizontal turbines and vertical turbines which have differences in the turbine shaft. Based on the description above, one of the solutions that can be proposed is the design of a windmill with a more practical and lightweight transmission system so that the wheel is able to produce the expected final rotation even though the wind speed that hits it is relatively low, as well as the construction of a pump that can work in low rotation. The results showed that the fastest time to fill 1000 ml of water was at an angle of 48º. Changes in the amount of angle are directly proportional to the shaft rotation speed. The highest pumping discharge is at the 48º pump tilt angle variation. The greater the rotation of the shaft, the greater the discharge value produced up to the 48º angle variation. However, for pump inclination angles of 41º and 54º there is a decrease in discharge value which is influenced by the more upright slope of the pump. This causes the potential force on the water to also be greater, so that the gap area traversed by water is getting bigger. The purpose of this study is to determine the effect of the tilt angle of the Archimedes screw pump driven by the avonius helical windmill on water debit.

I. Introduction

One of the most abundant sources of renewable energy is wind energy. Indonesia has the potential for low-speed wind because it is dominated by low-lying areas. Nonetheless, there are efforts to utilize wind energy through the development of Savonius helical type vertical axis wind turbine as a competitive renewable energy conversion system. Therefore, the optimal geometry configuration needs to be analyzed to convert low speed wind energy. Non dimensional parameters such as tip speed ratio (λ), coefficient of moment (Cm) and coefficient of power (Cp) of the turbine are analyzed using wind speed data sources in Indonesia. The Savonius helical windmill can be used as a wind energy conversion system for low wind potential in Indonesia and is recommended (Efendi, 2022) .

Wind turbines consist of two types, namely horizontal turbines and vertical turbines which have differences in the turbine shaft. Vertical type wind turbines are upright axis wind turbines with shaft movement and rotation parallel to the wind direction so that the rotation is in all wind directions. One type of vertical type wind turbine is the Savonius Helical which can rotate at low wind speeds and can receive wind from all directions. The advantages of the Savonis Helix type, namely attractive design, low torque change rate with efficiency < 40%, torque variation is relatively evenly distributed on each blade (Rosyid et al., 2020).

Research on a lobe pump model driven by a Savonius windmill was conducted. The pump model produced a small capacity (discharge 15 l/min and head 70 cm), so that to be applied in the field requires a very large Savonius dimension. This type of pump model is only suitable for areas that have wind potential with a minimum speed of 5 m/s. If the rotation is too low, the discharge produced by the pump is very little. Therefore, optimization of the length of the piston stroke and speed reduction in the transmission system are needed to produce optimum pump output (Supriyo & Suwarti, 2013).

Based on the description above, one of the solutions that can be proposed is the design of a windmill with a more practical and lightweight transmission system so that the wheel is able to produce the expected final rotation even though the wind speed that hits it is relatively low, as well as the construction of a pump that can work in low rotation. So in this study will use an Archimedes screw pump that can work in low rotation. The steps that can be taken to achieve this target are to make an appropriate Archimedes screw pump experimental tool with a suitable transmission system that can be used as an experimental study tool in utilizing wind potential in Indonesia.

II. METHOD

A. *Planning the Archimedes Screw Pump Experiment Station*

In design, there are many aspects that must be ensured. In designing a mechanical system, there are certainly requirements or criteria that must be met. This also applies in designing the Archimedes screw pump. The design of the Archimedes screw pump in this study is motivated by the prototype of the Savonius Helical windmill in the Energy Conversion Laboratory, Mechanical Engineering, Universitas

Trunojoyo Madura which is designed for power generation. The design of the Archimedes screw pump in this study utilizes the output of the existing Savonius helical windmill as a driving force. Based on that, some components in the previous design will be used as initial data for designing Archimedes screw pumps such as blades and tool frames. This Archimedes screw pump has criteria that must be met, including criteria regarding the pumping needs itself, specimens, to the transmission system, and so on. In designing this Archimedes pump, design is carried out on engine components, determining engine specifications and sizes, and selecting materials that are in accordance with the design.

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B. Maintaining the Integrity of the Specifications

A pre-existing helical savonius windmill is used as the motion input in this archimedes screw pump design. The construction of the helical savonius windmill uses a stainless steel plate as shown in Figures 1 and 1. The power of the windmill can be calculated using Equations

$$q = \frac{1}{2}\rho v^2 \quad (1)$$

$$P=F.v \quad (2)$$

$$F = q.A \quad (3)$$

obtained from wind speed data and the sweep area of the windmill blade.

Fig. 1. Construction of a helical savonius windmill.

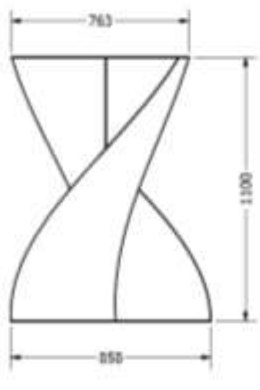

Fig. 2. 2D helical savonius windmill design in mm

Experiments in this study were conducted using a subsonic type wind tunnel. The wind speed parameter was varied from 1 m/s to 5 m/s. In addition, the pinwheel was also varied to its twist angle, which was 0˚, 22.5˚, 45˚, and 90˚ with the addition of an end plate ratio of 1.1. Windmill testing in the wind tunnel was carried out to determine the effect of variations in wind speed and twist angle on the rotation of the pinwheel produced..

III. Result and Discussion

The experiment was conducted using a wind speed of 8 m/s with a rotation of 52 rpm. Measurements were made of the time required for the pump to raise water to 1000 ml in each angle variation. Measurements made for each variation were repeated 3 times. The experimental data can be seen in Table 1.

TABLE I. AVERAGE TIME NEEDED TO PUMP 1000 ML OF WATER.

Angle	Universal Joint Angle	Replication 1 (sec)	Replication 2 (sec)	Replication 3 (sec)	Average time (sec)
36º	27º	257,4	256,2	253,2	255,6
39º	25,5º	205,2	207	208,8	207
42º	24º	186	181,8	184,8	184,2
45º	22,5º	132	123	126,6	127,2
48º	21º	86,4	87	82,8	85,40
51º	19,5º	120,6	122,4	121,2	121,40
54º	18º	135	136,8	137,4	136,40

Experimental results for a wind speed of 8 m/s that hit the blade of the Savonius windmill showed that the fastest time to fill 1000 ml of water was at an angle of 48º, while the longest time needed to fill 1000 ml of water at an angle of 35º. As for the highest discharge value of water pumping occurs at a shaft angle of 48º (amounting to 11.7 L / s) and the lowest discharge is obtained at a pump angle of 35º (amounting to 3.8 L / s). Water debit increased in the experiment shown on Table II.

TABLE II. WATER DEBIT INCREASED IN THE EXPERIMENT

Angle	Universal Joint Angle	Replication 1 (sec)	Replication 2 (sec)	Replication 3 (sec)	Average time (sec)	Debit (ml/s)	Shaft rotations (RPM)
36º	27º	257,4	256,2	253,2	255,6	3,9	47
39º	25,5º	205,2	207	208,8	207	4,8	48
42º	24º	186	181,8	184,8	184,2	5,4	50
45º	22,5º	132	123	126,6	127,2	7,9	52
48º	21º	86,4	87	82,8	85,40	11,7	53
51º	19,5º	120,6	122,4	121,2	121,4	8,2	54
54º	18º	135	136,8	137,4	136,4	7,3	55

The designed helical savonius windmill is capable of producing a power of 331.76 kg.m2/s3 and a shaft rotation of 72 rpm without loading the transmission system and pump. After assembly with the transmission system and pump, the shaft rotation obtained can be seen in table 4.3 with a torque value on the universal joint of 59.78 kg.m2/s2. From the calculation results, at an angle of 45º the water discharge that can be raised by the pump is Q = 9.86 ml/s. Meanwhile, from the experimental results, the water discharge that can be raised by the pump is Q = 7.9 ml/s. Thus, there is a difference between the results of theoretical calculations and experiments conducted, Table II shows that the fastest time to pump 1000 ml of water is at an angle of 48º with the longest time is at an angle of 36º. In Figure 4.2 the effect of angle on the rotational speed of the shaft can be interpreted that from an angle of 36º to an angle of 54º there is an increase in the value of rotation speed based on the amount of pump tilt angle. The increase in the trend is influenced by the smaller angle of the universal joint when the pump tilt angle is getting bigger as in table 4.3.

From the experimental results, the length of time to pump 1000 ml of water varies greatly based on the variation of the pump tilt angle formed. In the experimental results, the fastest time is at a pump inclination angle of 48º for 1.42 minutes, which at that time can produce a water discharge of 11.7 ml / s. The relationship between time and the resulting discharge can be concluded that the faster the time to pump water, the greater the discharge will be. In contrast to the research conducted by Rorres & Drexel (2018) which explains the optimal design results of the pump tilt angle at an angle of 38º. This is because the experiments carried out using the Savonius helical windmill with a universal joint transmission system. Universal joints have distinctive characteristics, namely in one rotation producing fluctuating output angular velocities with the value of the working angular velocity will be more optimal if the working angle on the universal joint is smaller (Kurniawan et al., 2022). In the Archimedes screw pump design, the pump angle is inversely proportional to the working angle of the universal joint. That is, the greater the pump angle, the smaller the working angle of the universal joint so that the rotational speed of the shaft will be greater and the water discharge will also be greater. However, at angles of 51º and 54º the decrease in discharge value is influenced by the more upright the slope of the pump, which causes the potential force on the water to also be greater. Where, the area of the gap traversed by water is getting bigger as in Figure 3

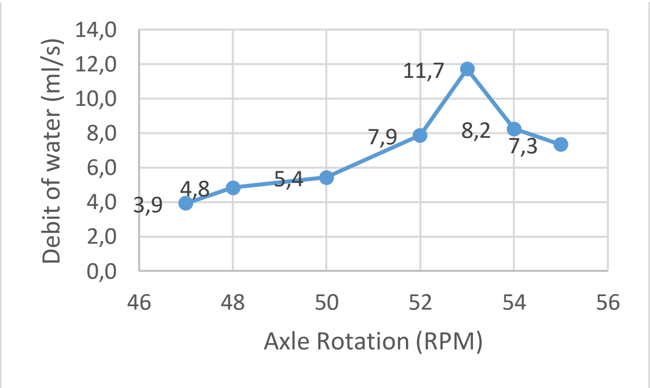

Fig. 3. 2D helical savonius windmill design in mm

IV. CONCLUSSION

The results showed that the fastest time to fill 1000 ml of water was at an angle of 48º. Changes in the amount of angle are directly proportional to the shaft rotation speed. The highest pumping discharge is at the 48º pump tilt angle variation. The greater the rotation of the shaft, the greater the discharge value produced up to the 48º angle variation. However, for pump inclination angles of 41º and 54º there is a decrease in discharge value which is influenced by the more upright slope of the pump. This causes the potential force on the water to also be greater, so that the gap area traversed by water is getting bigger.

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