Experimental investigation of Archimedes Screw Hydro Turbine rotation with and without deflector

Y Setiawan, E S Wijianti*, B S Wibowo, S Saparin, and P Prayitnoadi
Mechanical Engineering Department, Faculty of Engineering, Universitas Bangka Belitung, Indonesia
*E-mail: wijianti1903@gmail.com

Abstract. The Archimedes screw water turbine (AST) is a device that works mechanically to produce electrical energy with an energy source that comes from the flow of water. Archimedes screw hydro turbines operate at low head and flow rates and can generate electricity at micro levels. This type of turbine is very suitable for use in small waters such as irrigation and rivers. The research was conducted by building a prototype of a small-scale Archimedes screw hydro turbine with and without deflector. The purpose of this research is to compare the rotation produced by the two turbines and whether the installation of a deflector can improve turbine performance. The turbine is constructed with a screw length of 1 m, outer diameter is 30 cm, the number of blades 15, and each has a pitch distance is 1.3 cm. Turbine angle variations are 30°, 35°, and 40°. The results showed that the best rotor rotation was produced by the screw without deflector at an angle of 30°. This shows that the addition of a deflector reduces the resulting screw rotation.

1. Introduction
Currently, the use of renewable energy is still a challenge for the world [1]. For the sustainability of renewable energy to be maintained in the future, the use of renewable energy in a sustainable manner must continue to be developed and applied [2]. Hydro energy is a renewable energy source that is very economical and pollution-free [3]. This energy can be used and converted into electricity. This energy conversion is carried out through hydroelectric power plants. This type of power plant is without leaving greenhouse gas emissions as produced by power plants that use fossil energy. Unlike other renewable energy sources, water will continue to produce energy without stopping and its availability will continue to be generated by the hydrological cycle. Hydroelectric power plants are generated from the potential energy of water which is converted into mechanical energy by turbines. By utilizing the height and speed of the water, the energy is then converted into electrical energy with the help of a generator.

The screw-type water turbine or also known as the Archimedes Screws Turbine (AST) is one type of water turbine that has the potential as a small-scale power plant [4]. This screw-type water turbine is very environmentally friendly, equipped with a helix-shaped blade that surrounds a shaft [5]. In addition, this turbine can operate at a low head, capable of working at a low head less to 10m [6],[7],[8]. So it is very suitable to be applied to rivers in the territory of Indonesia. Besides, electricity transmission over long distances also becomes difficult to reach.

There are a lot of research on the Archimedes screw air turbine has been done, but it still doesn't have a fixed design for certain condition [8]. Several studies were conducted experimentally to find the relationship between the influence of several turbine performance variables, such as the effect of pitch, turbine slope, and screw angle to decide the rotational speed produced by the turbine. [9]. The shape,
number, pitch and slope, and dimensions of the AST blade affect the power produced [10],[11]. Irwansyah [12] has researched with a blade tilt of 30° at a flow rate of 0.02 m³/s producing 236.4 rpm rotation. Based on this research, this research will examine the effect of angle and the addition of a deflector on the turbine blades, the aim is to compare whether there is a significant effect on the rotation produced by the turbine.

2. Method

The research method used in this paper is experimental. Turbine performance testing was carried out in a water flow near a residential area located in Balunijuk Village, Bangka Belitung Province, Indonesia. Water discharge is a quantity that expresses the amount of water flowing during one second that passes through a wide cross-section. The water discharge test aims to find out how much water flows in unit volume per time. In this study, the measurement of water discharge in the modeling of a micro hydro power plant is carried out by dividing the volume of the vessel per time to fill the vessel. To reach a better water flow, the flow of water is dammed, so that the resulting discharge is 0.5 dm³/second.

2.1. Turbine design

Design of the turbines are without (Figure 1) and with a deflector (Figure 2). The variations of the turbine slope are 30°, 35° and 40°. The deflector is placed between the screw and the shaft on the same side along the screw sleeve. The purpose of using a deflector is to optimize the flow of water so that it enters and is directed to push the screw to rotate optimally. These two designs will be compared to get which performance produces better spin.

Figure 1. Turbine design without screw deflector

Figure 2. Screw design with deflector

The turbine head (h) is measured using the Pythagorean formula according to the variation of the turbine angle [8]:

\[ h = \sin \alpha \times L \]  

Where h is the head (m) and L is the length of the turbine screw (m). From the calculation, the turbine head for an angle of 30° is 0.5 m, 0.57 m when the angle is 35°, and 0.64 m for an angle of 40°. The rotation value obtained is the average value of the highest and lowest rounds produced. The test parameters for both turbine models are the same. The parameters of the AST design can be seen in Table 1 below:
### Table 1. Parameters of screw turbine design

| Parameters                | Value               | Unit |
|---------------------------|---------------------|------|
| Length of Turbine (L)     | 1                   | m    |
| Diameter of Outer Shaft   | 0.3                 | m    |
| Diameter of Inner Shaft   | 0.254               | m    |
| Angle (α)                 | 30, 35, 40          | Degree |
| Head (h)                  | 0.5, 0.57, 0.64     | m    |
| Pitch                     | 0.13                | m    |
| Water discharge           | 0.0005              | m³/s |

2.2. **Turbine testing**

The working principle of AST is that the water flowing through the dam enters the screw tube. The difference in height that occurs between upstream and downstream will create a pressure force that pushes the screw wall to produce rotation of the rotor. Figures 3 and 4 show the process of testing in the field that occurs naturally.

![Figure 3. Turbine design without deflector.](image1)

![Figure 4. Turbine design with deflector.](image2)

After the rotation test is carried out, the theoretical power calculation can be calculated using the formula:

\[ P_w = \rho \cdot g \cdot Q \cdot h \]  

(2)

Where \( P_w \) is the theoretical power (watt), \( \rho \) is the density of water (1000 m³/kg), \( g \) is the earth's gravity (9.81 m/s²), \( Q \) is the water discharge.

### 3. Results and discussion

Experimental tests on the effect of tilt angle on the performance of the AST with and without the use of a deflector have been carried out based on the parameters of Figure 1. The measured AST performance is screw rotation using a tachometer. While the theoretical power generated is calculated using formula 2 based on the resulting screw rotation. Measurements are repeated to get the highest and lowest rotations for several minutes, then the average rotation (rpm) that the screw can produce is calculated. The results of the study are shown in Table 2.
Table 2. Experimental Data

| Type           | Angle (Degree) | Average of Rotation (rpm) |
|----------------|----------------|--------------------------|
| Without Deflector | 30            | 376.95                   |
|                | 35            | 334.8                    |
|                | 40            | 315.25                   |
| With Deflector  | 30            | 155.53                   |
|                | 35            | 146.45                   |
|                | 40            | 140.25                   |

Base on Table 2, it can be seen that the best performance of AST with and without deflector is at an angle of 30°. This is because the water hits the most active part of the turbine and the sinking of the turbine is also balanced with the flow of water. Similarly, at the turbine head angle of 30° and above, the turbine rotation speed decreases because the water flow does not hit the active part of the turbine and the higher the water flow angle the turbine head will hit the top of the turbine. The average rotation that can be produced is 376.95 rpm. While the AST with a deflector, only able to produce the highest average rotation is 155.53 rpm. When comparing these results, AST without deflector has better performance than deflector. Several problems cause it, one of which is that the deflector mounted on the screw should not be on the same side. Installation on the same side causes gravity to be on only one side of the screw, so that the screw rotation becomes unstable and tends to be slower.

![Figure 5. Turbine design without deflector](image)

By calculating the theoretical power using the RPM generated from the experiment, the theoretical power is in the range of 2.35 – 3.01 watts, see Figure 5. The value of this theoretical power is indeed low, one of the causes of the low theoretical power is that the water discharge is too small. To get the optimum power, it should be done in river flows with higher water discharge. Another factor that affects the low rotation produced was the gap between the blades and the turbine housing that is too wide. This condition causes a lot of water flow through this gap. This causes the losses to be even greater.

4. Conclusions
Based on the results of the study, the addition of a deflector on the turbine screw has an effect on the resulting rotation, as well as the tilt of the screw angle. It is known that the AST with an angle of 30° without a deflector gives optimal rotor rotation results. This means that the deflector is not able to push the turbine to rotate the turbine better due to the gravity applied to it. The placement of the deflector
should be made in a circle following the groove of the screw, so that the loading does not occur only on one side.

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