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# Archimedes Screw Turbine Application on Portable Mini Hydropower Plant

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## Abstract

In this Turbine Design Analysis, we can obtain the necessary measurement results from one of the river locations where research is conducted. The original data for this objectivity was gathered by the authors through direct examination of the area or research site. This data was gained by three measurements: a direct survey of the location, quantitative measurements, and an analysis of the collected data. The authors obtain the necessary data such as differences in water level elevation (Head), Measurement of water discharge distribution (V), width of function on the river (L), and river area (A) and water discharge from the results of measurements to sites (Q). The tool's turbine efficiency has been calculated to be 55.6% based on the results of an analysis. Based on the acquired study, the developed turbine has two threads, a screw tilt angle of twenty-two degrees, and a length of eighty centimeters. In theoretical calculations, the hydropower's (PHydropower) generation power is 1114.42 Watt, the turbines (PTurbines) generation power is 664.2 Watt, and the generator's (PGenerator) generation power is 564.6 Watt. This value is used as a reference for selecting the type of generator to be utilized in the tool's design. Measurement of rotation of turbines the optimal turbine tilt angle for creating optimal turbine rotation is 30 degrees, resulting in a turbine speed of 402 revolutions per minute. The turbine tilt angle of 30 degrees (Optimal Angle) delivers the best results with an Electric Voltage (V) of 12.77 Volts and an Electric Current (I) of 2.51 Amps, according to the design tool's measurement data. Based on the results of an examination of electrical power output, a turbine tilt angle of 30° (Optimal Angle) delivers the best results with a residual power of 80 to 150 Watts when using a design tool suitable to steady and fast discharge conditions.

**Keywords:**
Design, Screw Turbine, Archimedes Screw Turbine, Hydropower Plant, Head Elevation Water

## 1. Introduction

Energy is unarguably the key factor in the current economic and social development of nations [1]. Along with population growth, this will surely lead to an increase in the demand for electrical energy, since almost all the activities carried out depend on electrical energy, while fossil energy as a source of energy is decreasing to meet the needs. in electricity from the people of Indonesia.

Research studies on the potential use of renewable energy sources, especially hydropower, need to be improved, including in the city of Palembang, which is one of the cities with many rivers. Rivers have electricity potentials that await to be harvested. Even rivers that do not have a sufficiently large drop can still be used as hydroelectric power stations thanks to the design of turbines to optimize the energy generated by the power stations [2].

There are many types of hydroelectric turbines that have been used in a hydroelectric power station, including cross-flow turbines, Kaplan turbines, propeller turbines, turbo turbines, Francis turbines, and Pelton turbines. Each type of turbine has its own function, so the choice of the type of turbine must be adapted to the existing water flow and the height of the waterfall [3].

The Archimedean screw turbine is a type of hydraulic turbine that has only been studied in recent years, the advantages of this turbine include: (i) it can operate at low heads (H < 10 m), (ii) it does not require fast piping, (iii) easy to install, (iv) easy to maintain and (v) does not harm the aquatic ecology or is environmentally friendly (clean energy) [2]. The Archimedean screw/turbine is made around the central tube/shaft, which has its own diameter (internal diameter), while the central tube/shaft has an extension at both ends [4]

The Archimedes Screw turbine is a type of screw turbine that can be operated at low head, by converting the kinetic energy and potential energy of water flow into mechanical energy in the propeller blades so that the turbine shaft rotates and that can be converted into electrical energy in the generator via transmission [5][6][7]. Hydroelectricity is a renewable electricity that respects the environment because this plant uses water as a driving force [8]. There are different classifications of hydroelectric plants according to the power generated, namely Micro Hydro below 100 kW, Mini Hydro with 100 - 500 kW and Small Hydro 500 - 10,000 kW [9][10].

Based on the potential of the energy produced, it is possible to pursue the use of watercourses/ streams with a flat course or of watercourses with limited height differences to become a hydroelectric plant with a power of less than 100 kW, optimizing the turbine project for the production of electricity energy that respects the environment (Clean Energy).

Acknowledging the potential for water energy in Palembang City through rivers dispersed throughout the subdistricts, a research was done to assess the flow rate of the river and the height of the waterfall. This research is directed at the residents of South Sumatra, particularly the city of Palembang, which has the potential for water energy but is not optimally utilized as a hydroelectric power plant. Study results will then be utilized to construct a portable hydroelectric power plant to generate electricity using the Archimedes turbine. The plant is capable of driving a generator, despite the operating principle of an ASG is fundamentally distinct from the majority of other types of microhydro power turbines [11].

The AST is one type of water turbine that has the potential for environmentally benign small-scale energy generation, whereas the screw-type water turbine is ideally suited for rivers in Indonesia since its functioning requires just a low turbine head [12]. The water turbine is one of the most important and expensive components of micro-hydro power plants, depending on the site-specific requirements [13]. This portable hydroelectric power station is anticipated to provide a solution for fulfilling electricity demands in regions with low-fall river flows.

## 2. Research methods

The initial step of this design is to determine the amount of river flow by observing different rivers in the Palembang City region. Fig. 1 depicts the river observation points where river flow and water level were measured in a tributary of the Musi River in the Nine-Seti Ilir Village of Palembang.

The instruments and materials utilized in this study include flow meters, sticks measuring river depth, stopwatches, roll meters, LEDs, Hollow iron, bearing pads, fastening bolts, wires, casings, turbines, multimeters, tachometers, generators.

Fig. 1. Observational River Location

The steps involved in designing the Archimedes screw turbine are:

1) 1) River observations, including measurement of the difference in water level elevation (Head), measurement of water flow velocity (V), and measurement of the width of the function in the river (L), and analysis of the area (A) and flow rate (Q) based on the findings of the observations [14].
2) Designing Archimedes screw turbine. The turbine design plan can be seen in Fig. 2. [15]

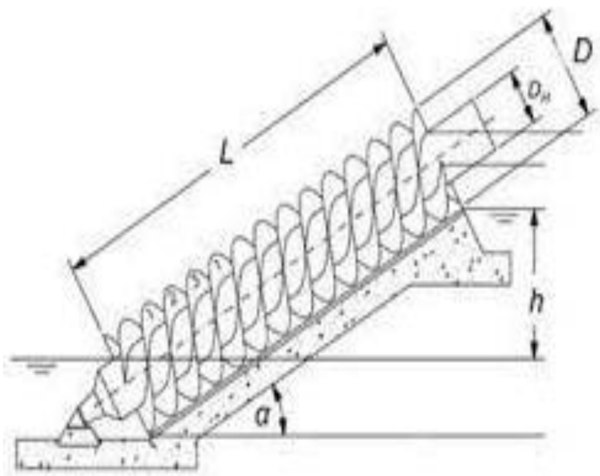


**Fig. 2.** Design Turbine Planning (Rorres, 2000)

3) Designing mini hydro power plant portable
4) Performance test, the performance test stage is carried out to test the finished tool design to match the planned amount of energy that has been calculated previously.

## 3. Results

### 3.1. Observational results

The height elevation flow ($h_1$) is at a water level elevation between the range of 60 cm and the lowest height ($h_0$) is at a water level elevation of about 20 cm. The results of the observations in table 1.

Using the results of the calculations in Table 1, the design of a mini portable hydroelectric turbine is continued, including the planning of the turbine angle plan, rotation speed, turbine diameter, turbine shaft diameter, screw angle, turbine length, turbine pitch plan, turbine thread number, and turbine efficiency. Head Measurement Scene in Fig. 3.

Tabel 1. Observational Measurement Data [9]

| Number | Data | Results |
|---|---|---|
| 1. | Head Elevation (H) | 40 cm |
| 2. | Water Flow (V) | 0.222 m/s |
| 3. | Functional Length (L) | 3.2 m |
| 4. | River Area (A) | 1.28 $m^2$ |
| 5. | Water Discharge (Q) | 0.284 $m^3/s$ |

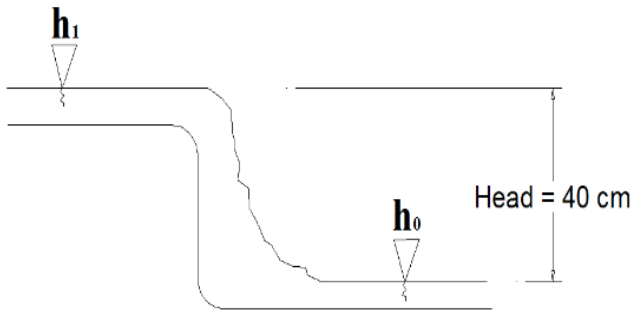


Fig. 3**.** Head Measurement Scene

### 3.2. Design of turbin dimensions

The results of the turbine design dimension analysis based on the data of Head, Discharge, speed, river width, and area to be designed are as follows:Turbine Type = Archimedes Screw; Screw Angle = 22 Degrees; Rotational Speed = 31 rpm; Outer Diameter = 30 cm or 0.3 m; Inner Diameter = 9 cm or 0.09 m; Turbine Angle = 30 Degrees; Length Turbine = 80 cm; Pitch Turbine = 1.2 D – 0.36; Number of Screw = 2.222 pieces in 80 cm; Efficiency Turbine = 55.6%. The results of the turbine dimension design in Fig. 4. While the results of the tool design dimensions in Fig. 5.

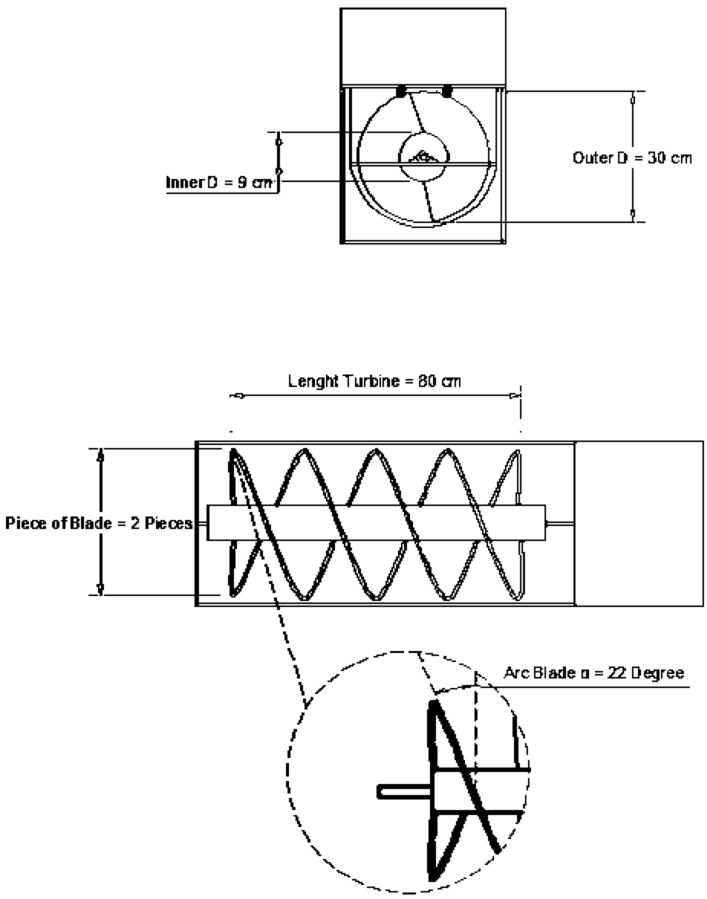


Fig. 4. The results of the turbine dimension design

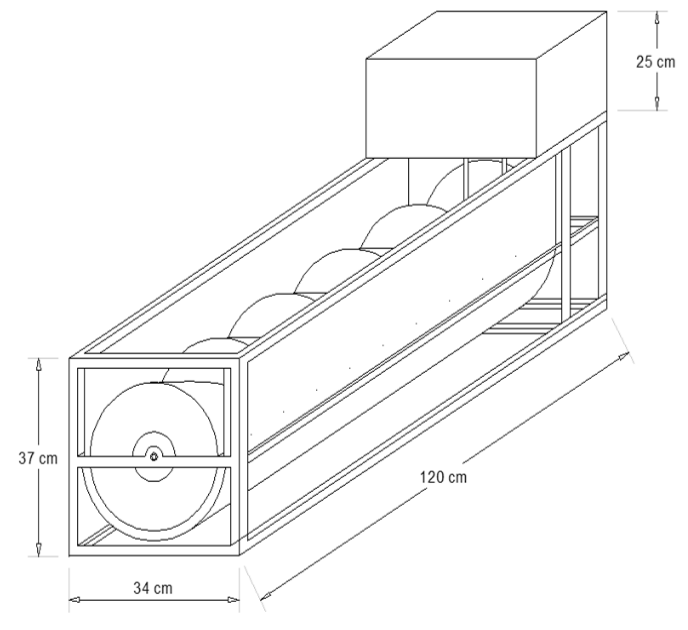


Fig. 5. Dimension Result of Mini HydroPower Plant Portable

This analysis is continued into the final stage, namely the detailed description of the turbine dimensions that have been analyzed.

### 3.3. Design mini hydro power plant portable

The final step is to compute the amount of energy created by the design of a portable micro hydropower system employing an Arcimedes screw turbine. Fig. 6 depicts the schematic of a tiny portable hydroelectric power station.

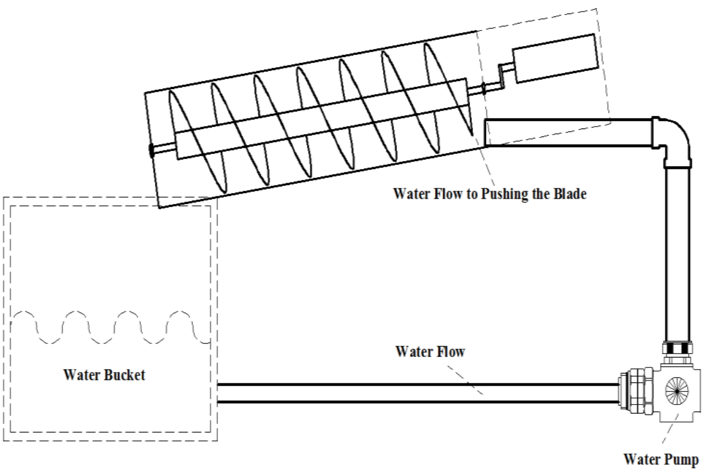


Fig. 6. Schematic Test in Mini Hydropower Plant Portable

From the results of the Calculation of Electrical Energy Power, PTurbines are obtained of 664.2 Watts, where the type of DC Generator used has a generation of 700-750 Watts, so that the calculation results obtained are close to the comparison variable of $P_{Turbine}$s, then $P_{Turbines}$ DC Generator = 664.2Watt 700 - 750 Watts.

### 3.4. Performance test in rotational speed (RPM)

The Turbine Rotation Performance Test is conducted by measuring the turbine's rotational speed with a digital tachometer. In order to measure the speed of the turbine's rotation, the Tacholaser is directed 1-2 times in the direction of the turbine's rotation point, which has been marked with a Reflective Sticker. The measurement findings acquired from this Turbine Rotation Performance Test will be given in Table 2.

Table 2. Performance Test Rotational Speed

| Water Discharge (m/s) | Angle Screw | Angle Turbine | Rotational Speed (rpm) |
|---|---|---|---|
| 0,284 $m^3/s$ | 22° | 25° | 347 rpm |
| | | 26° | 350 rpm |
| | | 27° | 356 rpm |
| | | 28° | 358 rpm |
| | | 29° | 360 rpm |
| | | 30° | 402 rpm |

From Table. 8 it can be seen that the right and efficient turbine tilt angle in producing optimal turbine rotation is at Angle (θ) = 30° with a turbine rotation result of 402 rpm. But the results can be optimized by changing the Diameter size of the pulley instead.

Spesification Pully:
1. Pully Turbine: Material Aluminium Diameter 3 Inch (7,62 cm)
2. Pully Generator: Material Aluminium Diameter OD100 – Diameter 10 cm

Asumstion from the Minimum rotation of generator between 600-800 rpm (Choose 600 rpm for the lowest). So, The Pully size had been changed inti 3 Inch Diameter. After changing the pully, re run the test again and Table 3 and Fig. 7 as a results of Optimized of rotational rpm eq. (1).

$$\frac{10\ cm}{7{,}62\ cm} = \frac{600\ rpm}{x\ rpm} \tag{1}$$

$$x = 457 \text{ rpm}$$

Tabel 3. Performance Test Rotational Speed Optimized.

| Water Discharge (m/s) | Angle Screw (°) | Angle Turbin (°) | Rpm | |
|---|---|---|---|---|
| | | | Turbin | Generator |
| 0,284 $m^3/s$ | 22° | 25° | 347 rpm | 592 rpm |
| | | 26° | 350 rpm | 611 rpm |
| | | 27° | 356 rpm | 621 rpm |
| | | 28° | 358 rpm | 632 rpm |
| | | 29° | 360 rpm | 636 rpm |
| | | 30° | 402 rpm | 638 rpm |

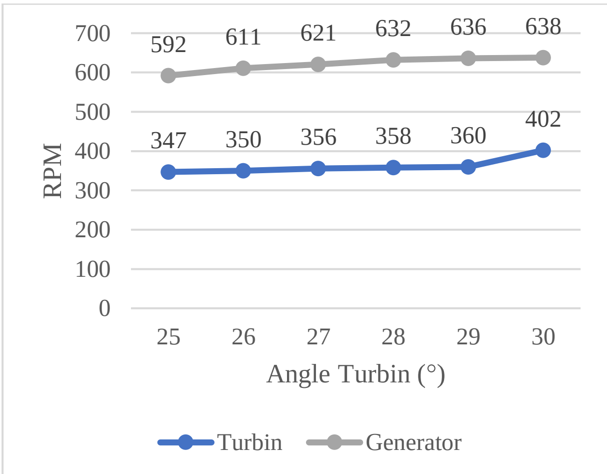


Fig. 7. Comparison Performance Test Rotational Speed

### 3.5. Performance test in voltage and electric current in design tool

Table 3 displays the measurement results of the Voltage (Volts) and Current (Amperes) of Electricity on the Design Tool, which were obtained using a Digital Multimeter to measure the voltage and current created by the Generator on the Design Tool.

Table 4 shows that the turbine tilt angle of 30° (Optimal Angle) produces the greatest results with an Electric Voltage of 44,3 Volts and an Electric Current of 3,39 Ampere with 150 Watt lamps loaded (6 Lamps x 25 Watt or 3 x 50 Watt Lamp – Each Lamp).

Tabel 4. Performance Test Voltage and Current Electrical in Hydropower Design

| Water Discharge (m/s) | Angle Screw (°) | Angle Turbine (°) | Voltage (Volt) | Current (Ampere) |
|---|---|---|---|---|
| 0,284 $m^3/s$ | 22° | 25° | 42,00 | 2,80 |
| | | 26° | 43,50 | 2,87 |
| | | 27° | 43,70 | 3,15 |
| | | 28° | 43,80 | 3,22 |
| | | 29° | 43,90 | 3,34 |
| | | 30° | 44,30 | 3,39 |

### 3.6. Electrical Power Analysis Tool

The results of the Electrical Energy Power Analysis on the Design Tool are presented in Table 4. Table 5 that the turbine tilt angle is 30° (Optimal Angle) which still produces the greatest results with power 150,18 Watts.

Table 5. The results of the Electrical Energy Power Analysis on the Design Hydropower Plant.

| Water Discharge (m/s) | Angle Screw | Angle Turbine | P Formula (*Watt*) | P (*Watt*) |
|---|---|---|---|---|
| Valve opening 100% 0,284 m3/s | 22° | 25° | P = V x I | 117,60 |
| | | 26° | | 124,85 |
| | | 27° | | 137,66 |
| | | 28° | | 141,04 |
| | | 29° | | 146,63 |
| | | 30° | | 150,18 |

### 3.7. Load test electrical

The results of the electrical power loading test using 3x50Watt (150Watt) LED lamps at a turbine angle of 30° still leaves a power generation of 150,18Watt. The results of the loading test in Table 6. Documentation of the load test results on the design tool is shown in Fig. 8.

Table 6. Results of Load Test Electrical

| Angle Turbine (°) | P (Watt) | Lamp 150 Watt |
|---|---|---|
| 30° | 150,18 Watts | Light On |

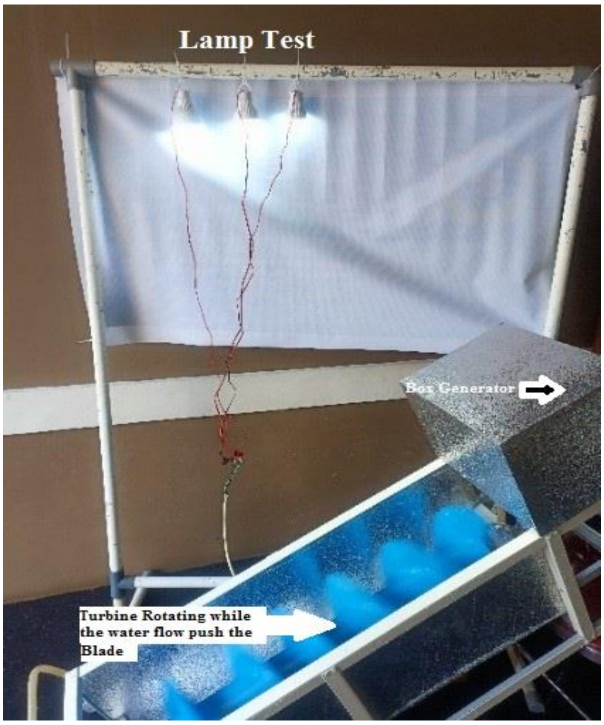


Fig. 8. Documentation of the load test resultson the design

The Load Test, while the water pumped by the water pump, the water flow and push the blade. When the water pushes the blade, it's make a blade rotating significant and continuously. While rotating, the blade pully makes a hub or connected with generator pully. So, the blade and generator rotating immediately compact, and make the electric processing. And then the test result, the Mini Hydropower Plant can give 150.18 Watts as a electric result.

## 4. Conclusions

The turbine efficiency has been calculated to be 55.6% based on the results of an analysis. Based on the acquired study, the developed turbine has two threads, a screw tilt angle of twenty-two degrees, and a length of eighty centimeters.

In theoretical calculations, the hydropower's (PHydropower) generation power is 1114.42 Watt, the turbines' (PTurbines) generation power is 664.2 Watt, and the generator's (PGenerator) generation power is 564.6 Watt. This value is used as a reference for selecting the type of generator to be utilized in the tool's design.

Measurement of Rotation of Turbines The optimal turbine tilt angle () for optimal turbine rotation is 30 degrees, with a turbine rotation result of 402 rpm in the Turbine and 632 RPM in the Generator.

The turbine tilt angle of 30 degrees (Optimal Angle) delivers the best results with an Electric Voltage (V) of 44,3 Volts and an Electric Current (I) of 3,39 Amperes, according to the design tool's measurement data.

Based on the results of an examination of electrical power output, a turbine tilt angle of 30 degrees (Optimal Angle) delivers the best results with a residual power of 100 to 150 Watts when using a design tool fitted to stable and fast discharge conditions.

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