A Micro Hydro Pelton Turbine Prototype (Review of the effect of water debit and nozzle angle to rotation and pelton turbine power)

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Abstract. This research began when the writer conducted a field study to Curup Tenang Bedegung Waterfall, Tanjung Agung District, Muara Enim, South Sumatra. The Curup Tenang Bedegung waterfall has the potential to build a micro-hydro Pelton turbine power plant. This study aims to see the flow rate and water discharge. From this preliminary study, the researcher decided to carry out the design of a micro-hydro Pelton turbine prototype on a mini scale but has optimal rotation and power. In this study, the analyses of the effect of water discharge were 20, 25, 30, 35, and 40 l/s and the nozzle angle was 50°, 55°, 60°, and 65° toward rotation and Pelton turbine power. From the results obtained, the higher the water discharge, the turbine rotation is increasing, the highest turbine rotation (691.3 rpm) achieved was at a water discharge of 40 l/s with a nozzle angle of 50°, the higher the water discharge will increase turbine power, the highest turbine power (15.89 watts) was obtained at a water discharge of 40 l/s with a 50° of nozzle angle.

Keywords: Pelton Turbine, Water Discharge, Nozzle Angle, Turbine Power.

1. Introduction
Energy is one of the important things in human life. The increased demand for energy can be an indicator of the increased prosperity, but at the same time, it also poses problems in its supply. To solve the problems of energy supply in Indonesia is by fully utilizing (full scaled) renewable potential energy. However, it is extremely difficult to construct a total centralized system of electricity supply by utilizing fully renewable energy as the only way to overcome the problem of energy supply in many parts of Indonesia. Based on these conditions, more detail decentralization of energy provision to seek the utilizing of new renewable that is environmental friendly energy in each region. Optimum utilizing the potential energy and facilities owned by Indonesian people hopefully can be a strategic solution. When house hold energy supply can be fulfilled independently, it will contribute
significantly to the national energy supply. The government has moved towards increasing the use of renewable energy with various efforts to utilize solar, wind and micro-hydro energy [1].

This research was conducted at Curup Tenang Bedegung waterfall, Tanjung Agung district of Muara Enim regency of South Sumatra. Data from Environmental Agency (Badan Lingkungan Hidup/BanLH) of South Sumatra provincial shows that new potential utilization of PLTMH in 2015 only reached 3.26% from 2.71% potential. Based on these data, the study continues by making a prototype generator of micro hydro Pelton turbine because it was designed in small scale based on clarification from hydropower plant. Type of micro hydro is <100 kW, Mini Hydro is 101-2000 kW, Small Hydro is 2.001-25.000 and large Hydro is > 25.000 [2]. In this study, a test was conducted by examining the effect of water discharge and nozzle angle. The instrument used was made on a scale that has small rotation and small power, and it is expected to be applicable at study location with more rotations and larger power turbines to utilize some energy resources available especially in Curup Tenang Bedegung at Tanjung Agung district in Muara Enim Regency, in his research, states that the use of water turbines especially Pelton turbines, is widely used. This type of turbine works by utilizing water fall/height (head) [3]. Various studies have been conducted to accelerate the flow by adjusting the dimensions of the turbine nozzle and the blade shape. The performance of a Pelton turbine is influenced by height, flow rate, angle, nozzle diameter, flow size and number of blades [4]. While in this study, the writer designed a Pelton turbine which can produce maximum turbine rotation and power by examining the effect of water discharge and nozzle angle.

2. Research Methodology

The research was conducted at Curup Tenang Bedegung Waterfall, Tanjung Agung District of Muara Enim Regency, and at the energy conversion laboratory of Mechanical Engineering of State Polytechnic of Sriwijaya started from July to December 2017.

The study on location used many devices such as GPS, current meter and ruler to measure the coordinates of test location, to measure the water flow rate, to measure the average water discharge, and to measure the length and the width of the rivers at the research location. The study at the energy conversion laboratory of Mechanical Engineering used a set of PLTMH simulation instruments. The design of water Pelton turbine equipped with pump 125Watt / 220 volt. Materials and tools used for the experimental purposes were 40 liters of fresh water, two incandescent light bulbs of 40 Watt, one incandescent light bulb of 60 Watt and one Stopwatch.

2.1. Research methods

The methods used in this study were Field Research and Laboratory Research. Field research aims to determine the condition of water flow rate and average river flow rate at three points of stream cross-section testing. The cross-section of stream flow I was 217.99 m³/s, the cross-section II was 63.13 m³/s, and section III was 77.79 m³/s so that the average water discharge from Curup Tenang Bedegung waterfall at Tanjung Agung District of Muara Enim regency was 119.63 m³/s. In laboratory observation, the water discharge arrangement used valve openings and water discharge reader using a flow meter. The water discharge flow rate was varied by five tests of 20, 25, 30, 35 and 40 l/s [5], and the nozzle angle was varied by 4 times testing of 50°, 55°, 60°, and 65° [6], and the results were used to compare the performance of the Pelton turbine. By using those methods, it can be seen the most optimum water discharge and nozzle angle to get the maximum rotation of Pelton turbine power.

2.2. The design of pelton turbine prototype

The research was conducted by using the design of Pelton turbine in form of micro-hydro scale tool which has the digital system of reading and measuring of rotation, current and power, and the measurement of water discharge used the flow meter. In this research, Pelton Turbine prototype design was based on PLTMH principles [7], where the flow of water was assisted by pumps that produce force flow like river or waterfall. Then by using the valve, the flow rate of the water going to the
The turbine was adjusted to fit the need through the reader device on the flow meter and fit with the variation of water discharge. Furthermore, one nozzle was used as an impulse to focus the flow, so it was more easily hit the turbine from various sides, the nozzle distance to the edge of 50 mm [8]. Nozzle shooting angle varied so there were variations to obtain the optimum conditions required. This tool used continuous cycles where the water hit the turbine was flown back to the holding tank, so it could be pumped return into the turbine. In general, this design was divided into 4 parts of the container, pump, nozzle, and turbine. A reservoir measuring 40 x 60 cm was installed at the bottom, so the water was easily circulated and pumped into the turbine.

In this study, the pump used was a centrifugal pump with 125 Watt energy requirements supplied through the power source. One 6 mm nozzle was used [9]. The Pelton turbine used 16 blades [10] with a thickness of 20 cm printed by using a mixture of tin and nickel. It was expected to have a lighter load to reduce the pressure to rotate the turbine. Alternator DC 12 Volt 9 Ampere 400 rpm was an electromechanical device used to convert mechanical energy into alternating current electric energy and a 1000 Watt AC inverter converted a 12 Volt DC current into a 220 Volt AC current. The design of PLTMH prototype is shown in Figure 1.

![Figure 1. Pelton Turbine Prototype](image)

3. Finding and Discussion

In this study, the purpose of the research location review and laboratory test was basically to determine the effect of flow rate and water velocity toward rotation and turbine power.

3.1 Location of data collection

This research was conducted at Curup Tenang Bedegung Waterfall, Tanjung Agung, Muara Enim, South Sumatra. The coordinate of study location according to GPS was located at 4° 03’30.32”S103° 6’00.08”E. It was located in the southern part of Muara Enim and took 3 hours of travel time or 210 km from Palembang. There was a 600 meter path built on the bank of the river and a bridge across a small stream. The coordinate of the research location is shown in Figure 2.
3.2 The results of field study
Based on the field survey results obtained, the water flow rate at cross-section I was 13.818 m/s and the water discharge was 217.986 m³/s. In section II, the flow rate was 4,056 m/s and the water discharge was 63,126 m³/s. At cross-section III, the flow rate was 4,477 m/s and the water discharge was 77.785 m³/s.

From the data above, section I was the largest flow rate, it was due to the location near the waterfall location, at cross section II the flow rate decreased due to located at the middle, flat and washy, while at cross-section III, the flow rate rose because of its position near the waterfall location. The result of this field study furthermore became a consideration in determining flow rate in laboratory scale Pelton turbine.

3.3 The test results of the effect of a water debit and nozzle angle to turbine rotation
The test results of the effect of water discharge of 20, 25, 30, 35, and 40 l/s with the nozzle angle of 50°, 55°, 60°, and 65° obtained that the highest rotation was at 40 l/s with the nozzle angle of 50° and produced the rotational speed of 691.3 rpm. The lowest rotation was at 20 l/s with the nozzle angle of 50° and produced the rotational speed of 310 rpm. The results of turbine rotation are shown in Table 1 where the results of this study were also in line with research conducted [11] that the greater the angle used, the smaller rotational speed and the smaller the power produced.
Table 1. The data of test result of the effect water debit and nozzle angle toward turbine rotation

| No | Water Debit (l/sec) | Nozzle Angle (°) | Turbine Rotation (rpm) |
|----|---------------------|-----------------|------------------------|
| 1  | 20                  | 50              | 310                    |
|    |                     | 55              | 300                    |
|    |                     | 60              | 231                    |
|    |                     | 65              | 201                    |
|    |                     | 50              | 431.1                  |
| 2  | 25                  | 55              | 400.6                  |
|    |                     | 60              | 272.2                  |
|    |                     | 65              | 231.2                  |
|    |                     | 50              | 445.2                  |
| 3  | 30                  | 55              | 411.6                  |
|    |                     | 60              | 372.2                  |
|    |                     | 65              | 283.3                  |
|    |                     | 50              | 446.2                  |
| 4  | 35                  | 55              | 412.7                  |
|    |                     | 60              | 375.3                  |
|    |                     | 65              | 293.3                  |
|    |                     | 50              | 691.3                  |
| 5  | 40                  | 55              | 655.5                  |
|    |                     | 60              | 639.5                  |
|    |                     | 65              | 630.3                  |

3.4 Test result of the effect of water debit and nozzle angle toward turbine power

The test result of the effect of water discharge of 20, 25, 30, 35, and 40 l/s with the nozzle angle of 50°, 55°, 60°, and 65° obtained that the highest power was 15.89 watts at the water discharge 40 l/s with the nozzle angle of 50°. At the water discharge of 20 l/s with the nozzle angle of 50°, it was obtained that the highest power was 3.14 watts. The results from the nozzle angle to the turbine power is shown in Table 2 which the results of this study were also in line with a research conducted [12] that the faster the runner speed generated, the greater the values of electric power generated. On the other hand, the weaker the rate of rotation generated by the runner the lower the values of electric power generated.
Table 2. The Data of Test Results of The Effect of Water Debit and Nozzel Angle Toward Turbine Power

| No | Water Debit (l/sec) | Nozzle Angle (°) | Turbine Power (watt) |
|----|---------------------|------------------|----------------------|
| 1  | 20                  | 50               | 3.14                 |
|    |                     | 55               | 13.12                |
|    |                     | 60               | 1.52                 |
|    |                     | 65               | 1.7                  |
|    |                     | 50               | 11.79                |
|    |                     | 55               | 11.7                 |
| 2  | 25                  | 60               | 10.7                 |
|    |                     | 65               | 7.28                 |
|    |                     | 50               | 14.4                 |
|    |                     | 55               | 14                  |
| 3  | 30                  | 60               | 11.7                 |
|    |                     | 65               | 11.2                 |
|    |                     | 50               | 15.4                 |
|    |                     | 55               | 14                  |
| 4  | 35                  | 60               | 11.76                |
|    |                     | 65               | 11.52                |
|    |                     | 50               | 15.89                |
|    |                     | 55               | 14.78                |
| 5  | 40                  | 60               | 14.56                |
|    |                     | 65               | 14                  |

3.5 The effect of water discharge and nozzle angle toward turbine rotation

At the water discharge of 20 l/s with the nozzle angle of 65° it was obtained that the lowest rotational speed was 201 rpm. Turbine rotation increased to 630.3 rpm at the water discharge of 40 l/sec with the nozzle angle of 65°. Turbine produced a rotational speed of 691.3 rpm at water discharge of 40 l/s with the nozzle angle of 50°. It could be concluded that the higher water flow, the faster the turbine spins, and the nozzle angle was very affecting in producing optimum turbine rotation, it is shown in Figure 3.

![Figure 3. Effect of water debit and nozzle angle toward turbine rotation](image)

3.6 The effect of water debit and nozzle angle on turbine power

The lowest and the highest water debit test results toward turbine power were obtained at the water discharge of 20 l/s with the nozzle angle of 65°. The turbine rotated at a rotational speed of 201 rpm...
and produced 1.7 watt. At the water discharge of 20 l/s with the nozzle angle of 50°, the turbine produced a rotational speed of 310 rpm and the power generated was 3.14 watts. While at water debit of 40 l/s with the nozzle angle of 65°, the turbine produced a rotational speed of 630.3 rpm and the power generated was 14 watt. At the water discharge of 40 l/s with the nozzle angle of 50°, the turbine produced a rotational speed of 691.3 rpm and the power generated was 15.89 watt. The higher the water flow, the faster the rotation and the greater the turbine power generated. It is shown in Figure 4.

![Figure 4](image)

**Figure 4.** The effect of water debit and nozzle angle toward turbine power

4. Conclusion
From the results of the study, the prototype of Pelton Micro Hydro Turbine was tested with water discharge of 20, 25, 30, 35 and 40 l/s with the nozzle angle of 50°, 55°, 60° and 65°. It was obtained that the highest rotation was at 40 l/s with the nozzle angle 50° and it produce a rotational speed of 691.3 rpm. The lowest water discharge of 20 l/s with the nozzle angle of 65° obtained the lowest rotational speed, 201 rpm. Thus, the nozzle angle greatly affected the turbine spin.

At the water discharge of 40 l/s and the rotational speed of 691.3 rpm, it was obtained that the highest power was 15.89 watts. At the water debit of 20 l/s and the rotational speed of 310 rpm, it was obtained that the highest power was 3.14 watts. It could be concluded that the greater the water debit and turbine rotational speed, the greater the Turbine power generated.

With the high average of water flow at Curup Tenang Bedegung waterfall of Tanjung Agung, Muara Enim, 119.63 m³/s, it was possible and potential to build a micro hydro power plant with a greater rotation and power, resulting from the laboratory test with 40 liters of debit could produce a rotational speed of 691.3 rpm and a power of 15.89 watts. However, not only high debit but also nozzle angle greatly affected the results of turbine rotational speed and power. Hopefully this study can be applied and realize to build a bigger Micro hydropower plant and has a maximum rotation and power, especially at Curup Tenang Bedegung Waterfall of Tanjung Agung District of Muara Enim Regency, South Sumatra.

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