**BLADE SHAPE ANALYSIS ON THE PERFORMANCE OF THE PELTON TURBINE PROROTIPE**

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**Abstract – Water turbine is one of the driving machines where the working fluid is water that is used directly to spin the turbine runner. This research was conducted using a pelton type water turbine installastion with variations In the shape of the turbine blade. The research method used is an experimental method with a laboratory scale experimental design as well as the results of the design of this water turbine used as a practical tool for students majoring in mechanical engineering. The results showed the influence of turbine blade shape on the performance of the pelton water turbine prototype, so it can be concluded that the maximum tangential velocity is 12.141 rad/s, the hydraulic power value is 2.64 Watts, the kinetic power value is 3.886 Watts, maximum turbine power 99.141 Watts, maximum electric generator power 99.141 Watts, maximum turbine efficiency 25.512 %, and maximum electric generator efficiency 0.661 %.**

***Keywords: Analisis, Blade shape, Performance, pelton turbine***

# Introduction

 A water turbine is one of the driving machines where the fluid works are the water that is used directly to spin the turbine wheels. In the turbine wheels, there is a blade and fluid work flowing through the phone between the blade.[1] A Pelton turbine is an impulse turbine, which is a turbine-driven by an energy kinetic water. High-accuracy water sprays about the blade and after moving the water runner out at low speeds, meaning that some of their energy is not absorbed by the runner. Water pressure in and out of the blade is atmospheric pressure. [2] The laboratory is a place to train students in terms of practicing skills, demonstrations, experiments, research, and the development of science. The existence of the laboratory as a place of the practicum is necessary to improve student skills. The implementation of practical activities is conducted in the provision of learning experience to the students so that students can interact with lesson materials and direct observation of symptoms that occur in the water turbine test equipment. Practice activities in the laboratory can improve student skills when used efficiently because with the experiments students can understand the courses that require a concrete passion by doing real activities through Experiment. [3] Similar research conducted by the author of the year 2017 with a variation of the shape of the blade against torque and power of water turbine and a variation of turbine nozzle diameter with the turbine round braking method. This advanced research by modifying the water turbine designed by previous authors with different methods of prior year's research so that it can explain how the performance of the prototype Pelton water turbine has been modified When using the turbine blade shape variation. The shape of the turbine blade greatly determines the rotation of the turbine so that it can improve turbine performance. For that, the research is aimed at determining the proper shape of the blade to produce maximum turbine performance.

# Research Methodology

# The study was conducted using an experimental method with a laboratory-scale experimental design using Pelton type water turbine equipment as shown in Figure 1 by testing the shape of the turbine blade.

**Variable Research**

The variables used in this study were three that were free variables, bound variables and controlled variables.

A. Variable-free

The free variables on this study consist of:

1. Water discharge: 0.0005 m3/s

2. Total of 18-piece turbine

3. The shape of the spoon include: a flat blade, a curved spoon, a half-cylinder blade, a teaspoon of rice, and a blade bowl.

B. Variable controlled

1. A blade angle is conditioned constant at 90o position.

2. Turbine nozzle size 1/2 inches

C. Variables bound

The variables tied to this research are angular velocity, hydroelectric power of water, kinetic power of water, turbine power, electricity generator power, turbine efficiency and power generator efficiency.

**Research procedure**

The testing procedure for the retrieval of research data is as follows:

1. Create a table to record the test results.

2. Preparing and installing all research installations and measuring instruments used.

3. Install the nozzle 1/2 Inch size as specified.

4. Install a flat turbine Sudu shape first for data retrieval.

5. Check all the turbine components studied to ensure readiness before starting to turn on the water pump and make sure all the measuring instrument conditions are in good condition.

6. Press the switch/button to turn on the water pump.

7. Measure the discharge of water flow using the flowmeter measuring instrument, and record the result of the measurement.

8. Measure the rotation of the turbine shaft and round the generator shaft with the tachometer gauge, then record the turbine rotation value on the tachometer gauge.

9. Measures the output voltage and output current on the turbine generator that is loaded with the lamp and records the value of the power voltage and electric current on the Multi tester gauge.

10. Repeat the data retrieval step beginning number four by attaching the shape of the curved spoon, rice scoop, half-cylinder, and the spoon-bowl shape until the data retrieval step number nine.

11. Processing and analyzing the research data obtained to determine the performance value of the water turbine studied.

12. Draw conclusions from the results of the research done.

**Installation of Research Tools**

The dimension of research equipment is 110 cm long, width 60 cm, and height 40 cm made of iron plate elbow. The water container size of 60 cm x 60 cm is made of a sheet of the iron plate with a thickness of 0.3 cm. While the runner size of the turbine is 21.5 cm in diameter. While the turbine shaft size is 2.54 cm diameter with a length of 80 cm. In this research testing tool, The used water turbine is a type of horizontal shaft Pelton whose research installation design is shown in Figure 1.



Figure 1. Design Installation research

Image description 1:

1. Water pump

2. Electricity generator

3. 12 Volt Battery

4. V-belt

5. Pully

6. Turbine Installation Frame

7. Flowmeter

8. 1 inch PVC pipe

9. Water Collection Tank

Pelton water turbine testing is expected to get maximum turbine performance.[5] The calculation process for obtaining turbine performance using equations 1 through equation 11: [2,9]

 **1. Cross-sectional area of ​​the nozzle tip (A)**

         To calculate the cross-sectional area of ​​the nozzle tip, use equation 1.

  (1)

Where:

A = Extent tip nozzle (m2).

D = inside diameter of the nozzle (m)

**2. Flow Capacity (Q)**

       To calculate the flow capacity using equation 2.

 $Q=A .V$ (2)

Where:

  Q  = Discharge of water flow (m³ / s).

 A = Extent tip nozzle (m2).

 V = Flow velocity (m / s).

**3. Flow Speed ​​(V)**

       To calculate the flow velocity using equation 3.

 $V=\frac{ Q}{A}$ (3)

Where:

 V = Flow velocity (m / s).

    Q = Discharge of water flow (m³ / s).

 A = Extent tip nozzle (m2).

**4. Flowing Mass of Water ()**

      To calculate the mass of the flow using equation 4.

 $\dot{m}=ρ . Q$ (4)

 Where:

      $\dot{m}$= Mass water flow rate (kg / s)

      $ρ$ = Density of water (kg / m3).

       $Q$= Discharge of water flow (m³ / s).

**5. Angular Speed ​​(ω)**

To get the angular velocity value use equation 5.

 $ω= \frac{2. π.n}{60}$ (5) Where:

  $ω$ = Angular Speed ​​(rad / s)

  n = turbine rotation (rpm)

**5. Calculation of Power:**

a. Hydraulic power.

Hydraulic power is calculated using equation 6.

 Ph= ρ.g.Q.H (6) Where:

 Ph = hydraulic power (Watt)

    ρ = Density of water 996.74 (kg / m3).

 g = Earth's gravity force, 9.81 (m / s2).

   Q = Discharge of water flow (m3 / s).

 H = turbine head (m)

b. Kinetic power of water jets

The kinetic power of water is calculated using equation 7.

 $P\_{k} =\frac{1}{2}.ρ.A .v^{3}$ (7)

 Where:

 $P\_{k}$ = Kinetic power of water (Watts).

  $ρ$  = Density of water 996.74 (kg / m3).

 $A$ = Turbine nozzle cross-sectional area (m2).

 $v$ = Flow velocity (m / s).

**c. Turbine Power;**

To calculate the turbine power use equation 8.

 Pt = ρ. A. ω. (Ω - v). (1 + cos θ).V (8)

Where:

Pt = water turbine power (Watt).

 ρ = Density of water 996.74 (kg / m3).

A = Turbine nozzle cross-sectional area (m2).

 ω = Angular velocity (rad / s).

 v = Flow velocity (m / s).

 cos θ =

**d. Electric Power (Generator Power)**

To calculate electric power using equation 9.

 Pg = V. I. Cosϕ (9) Where:

Pg = electric power (generator power); (Watt)

V = Electric generator output voltage; (Volt)

I = Electric generator output current; (Ampere)

Cosϕ = Power factor (degree)

**6. Calculation of Efficiency:**

a. Turbine Blade Efficiency;

To calculate the efficiency of a turbine use equation 10.

 $η\_{t}=\frac{P\_{t}}{P\_{k}}x100\%$ (10)

Where:

ηt = water turbine efficiency (%).

Pt = turbine power (Watt).

Pk = kinetic power of water (Watts).

b. Turbine generator efficiency:

To calculate the efficiency of a generator using equation 11.

 $η\_{g}=\frac{P\_{g}}{P\_{h}}x100\%$ (11)

Where:

$η\_{g}$  = turbine generator system efficiency (%).

Pg = turbine generator power (Watt).

Ph = water hydraulic power (Watt).

**III. Results and Discussion**

 These tests were conducted to obtain turbine round data, generator rounds, power output naps, electric generator output currents, turbine heads, and flow discharge. Data analysis techniques using descriptive techniques based on the results of the research conducted, from the field test data conducted then carried out data processing or mathematical calculations as shown in 1 to the 11th formula with Objectives for obtaining the value of hydraulic power, kinetic power, turbine power, power generators, turbine efficiency, and generator efficiency. The results of the data processing are then used in graphical form to see the trending phenomenon of the turbine-shaped chart to the performance of Pelton water turbine. The relationship between the turbine-shaped blade-performance of the Pelton water turbine is shown 2 to 8 figures.

Figure 2. Graft the number of blades VS Tangential speed

Based on Figure 2 the relationship of the shape of the turbine blade to tangent speed. The maximum tangential velocity occurs in the shape of the bowl blade, then the power of the second turbine occurs in the curved blade, the third tangential speed occurs in the half-cylinder blade, the fourth Tangential velocity occurs in the rice spoon blade, and the lowest tangential velocity occurs in the flat blade. The shape of the blade influences tangential velocity, the more precise the shape of the turbine blade will increase the turbine rotation and the turbine speed will affect the tangential force produced. The maximum tangential velocity occurs in the form of a blade of blades with a value of 12,141 rad / s and the lowest tangential velocity occurs in the shape of a flat blade with a value of 7117 rad / s.

Figure 3. Graft the number of blades VS water hydraulic power

Base on field testing data which is then performed mathematical data processing using equation 6, it can be concluded that the shape of the blade does not affect hydraulic power of the water, because in this study using the same flow rate and turbine head so that there is no difference in the hydraulic power value of water. The value of hydraulic power in this study was 2.64 Watt

Figure 4. Graft The number of Blades VS Water Kinetic Power

Based on field testing data which is then performed mathematical data processing using equation 7, it can be concluded that the shape of the blade does not affect the hydraulic power of the water, because in this study using a turbine nozzle size so that the speed of water flowing out through the nozzle at each turbo blade shape test is the same. From the results of research data processing the kinetic power value of water in the study amounted to 3,886 Watt.

Figure 5. Graft the number of blades VS Turbine Power

Based on the field testing data which is then performed data processing using equation 8, it can be concluded that the shape of the blade affects the turbine power. Based on Figure 5, the maximum turbine power occurs in the shape of a bowl blade, then the second turbine power occurs in the curved blade, the third turbine power occurs in a half-cylinder blade, the fourth turbine power occurs in the rice spoon blade, and the lowest turbine power occurs in a flat blade. From the results of data processing it can be concluded that the maximum turbine power value is 99,141 Watt and the lowest turbine power is 22,476 Watt

Figure 6. Graft The number of Blades VS Electric Generator Power

Based on field testing data which is then performed data processing using equation 9, it can be concluded that the shape of the blade affects the power of the electric generator (electric power). Based on Figure 6, the maximum electric generator power occurs in the shape of a bowl blade, then the second electric generator power occurs in a rice spoon blade, the third electric generator power occurs in a half-cylinder blade, the fourth electric generator power occurs in a curved blade, and the lowest electric generator power occurs on a flat blade. From the results of data processing it can be concluded that the maximum power generator value is 99,141 Watt and the lowest power generator is 22,476 Watt.

Figure 7. Graft the shape of Blade VS Turbine efficiency

Based on field testing data which is then performed data processing using equation 10, it can be concluded that the shape of the blade influences the efficiency of the turbine. Based on Figure 7, the maximum turbine efficiency occurs in the shape of a bowl blade, then the efficiency of the second turbine occurs in the curve of the turbine blade. The efficiency of the third turbine occurs in the half-cylinder blade, the efficiency of the fourth turbine occurs in the rice spoon blade, and the lowest turbine efficiency occurs in the flat blade. From the results of data processing it can be concluded that the maximum turbine efficiency is 25,512% and the lowest turbine efficiency is 5,784%.

Figure 8. Graft the shape of Blade VS Electric Generator Efficiency

Based on field testing data which is then processed using data equation 11, it can be concluded that the shape of the blade affects the efficiency of the electric generator. Based on Figure 8, the maximum efficiency of the electric generator occurs in the shape of a bowl blade, then the efficiency of the second electric generator occurs in the spoon of the rice spoon, the efficiency of the third electric generator occurs in a half-cylinder blade, the efficiency of the fourth electric generator occurs in a curved blade, and the lowest efficiency of the electric generator occurs on a flat blade. From the results of data processing, it can be concluded that the maximum value of the efficiency of electric generators is 0.661% and the lowest efficiency of electric generators is 0.002%.

# IV.Conclusion

 The results showed the influence of turbine blade shape on the performance of the Pelton water turbine prototype, so it can be concluded that the maximum turbine performance occurs in the shape of a bowl blade where the maximum tangential velocity is 12,141 rad / s, the hydraulic power value is 2.64 Watt, the kinetic power value is 3.886 Watts, maximum turbine power 99,141 Watts, maximum electric generator power 99,141 Watts, maximum turbine efficiency 25,512%, and maximum electric generator efficiency of 0.661%.

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