

Experimental Study of The Alternative Analysis of Cross-Section Variety of Half-Circle, Bowl and Isosceles Triangle to Generate Electricity: A Case Study of Pico Hydro-Pelton Turbines in ITATS Surabaya

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ABSTRACT

One of the main urgencies of a developing country such as Indonesia is developing energy supply. Under the government regulation, Indonesia thrives the supply of electricity which mainly maintain by fossil fuels such as oil, gas and coal. This energy supply is limited from time to time. To alternate the condition, environment-friendly energy sources need to be developed. One such energy source is Pico hydro with the use of the concept of a hydroelectric power generator. As we know, this type of generator proven only useful in small, remote communities balanced with a small amount of electricity and considerably function with the Pelton turbines. This study focuses to maximize the valve opening of Pelton turbines to give a good distribution system to generate the electricity. The variety of valve opening of 18⁰, 36⁰, 54⁰, 72⁰ and 90⁰ are matched to the variety of cross-section of the half-circle, bowl and Isosceles Triangle. The result of this research is that the greater the valve opening the greater the efficiency system. Type of bowl blade results in greater efficiency of the system than the semicircular and isosceles triangular blade.

Keywords: Variety of Valve Openings, Pelton, LED, Half-Circle Blade

INTRODUCTION

Indonesia is well-known with a great archipelago island living with 270 million people, emerging as a middle-income country under the condition of development in economic, industrialization as well as urbanization. This development is interrelated to the demand for energy supply, in particular mixed with the enormous population. In fact, the government continued support to provide a green sustainable energy supply, but the factor of efficiency still become a burden especially in the remote area. Pico hydro come with the solution of the hydroelectric power proven to be allocated in a small, remote area that can maximize the function of use electricity. Pico-hydro setups are also practiced running by streaming with a small weir, pipes, Pelton-turbine valve and some common supported tools. In addition, typical like other hydroelectric and green source power generation, consumption of fossil fuels is maximally reduced. Some advantages of this system not limited to: (1) Utilizing zero pollutants, mainly used water as the parameter energy with a very low head system between 1 to 3 meters with a large discharge, (2) Easy installation and environmentally friendly for aquatic organisms and, (3) Suitable for small, remote communities [1].

Several studies on pelton turbines that can be used to generate electrical energy have been carried out by researchers abroad, including [2][3][4][5].

Pico hydro is a power plant that uses water as the driving force of the blade in the turbine which will drive the generator to produce electrical energy. In principle, Pico hydro is utilizing the flow rate of water which functions to drive the turbine that connects to the generator. Several studies on Pelton turbines can produce electrical energy by previous researchers. Research on "Experimental study of variation of the effect of the Pelton turbine valve opening on electrical energy that has produced to turned on a laptop" has been conducted by [6]. Variations of valve openings are 18°, 36°, 54°, 72° dan 90°. The results showed that the duration of charging the laptop to 100% from the initial 0% condition takes about 138 minutes or 2 hours 18 minutes.

A study on the effect of the number of nozzles on the Pelton turbine. Tests were carried out with 3 variations of pressure (head), i.e., 2 kg/cm², 2,5 kg/cm² dan 3 kg/cm²[7]. From the test results, it is found that with 1 nozzle the efficiency is higher, where at the head of 30 m. If using 1 nozzle the output power is 9.51 Watt, while if using 2 nozzles the output power is 9.41 Watt.

Research on the performance analysis of the Pelton turbine-type hydropower system with variations in valve openings and lamp loads using an inverter was carried out[8][9]. The turbine used in this study was a Pelton turbine with an inverter. Comparison of various lamp power, such as 3, 5, 9 and 12 Watt was analyzed. The results showed that the greater the valve opening, the greater the

electric power produced, for example, 90° valve openings with a 9 Watt lamp load, the highest power was obtained at 1.765 Watt.

The Pelton turbine prototype as alternative energy for micro-hydro in Lampung[10]. The research variation is to use a variation of the discharge with the following amounts of discharge 0,00043 m³/sec, 0,00046 m³/sec dan 0,0005 m³/sec. In this study, the highest power was obtained at a discharge of 0.0005 m³ /sec with a value of 4.97 Watt for blade 40. The highest efficiency was at a discharge of 0.0005 m³/sec with a value of 49% at blade 40.

However, from this previous research, research on variations in the shape of Pelton turbine blades on the electric power generated in water installations at ITATS has never been done before. The contribution of this research is as a database for researchers on the importance of the influence of the blade shape on the productivity of supplying electrical energy.

RESEARCH METHOD

Performance of system description as illustrated as a step as a follows: Water in the tendon with a height of 20 has potential energy. Through the pipe, the tendon is connected to the water valve so that the water flows. When water at the valve, the water has kinetic energy and when the valve is opened the water flows into the manometer. The manometer is used here as a monitor to ensure constant pressure, from the water manometer to the nozzle. The

function of this nozzle is to maximize kinetic energy. From the nozzle, the water hits the turbine blade, and the turbine rotates. The turbine shaft is connected to the generator so that the generator rotates and produces electrical energy in the same direction. Electrical energy from the generator is stored by the battery before it is connected to the inverter. The function of this inverter is to change the direct current with a voltage of 12 volts and a strong current of 3 amperes into alternating current with a voltage of 220 volts (PLN electricity). Electrical energy from the inverter that is following the needs of the laptop to the laptop and can turn on the laptop.

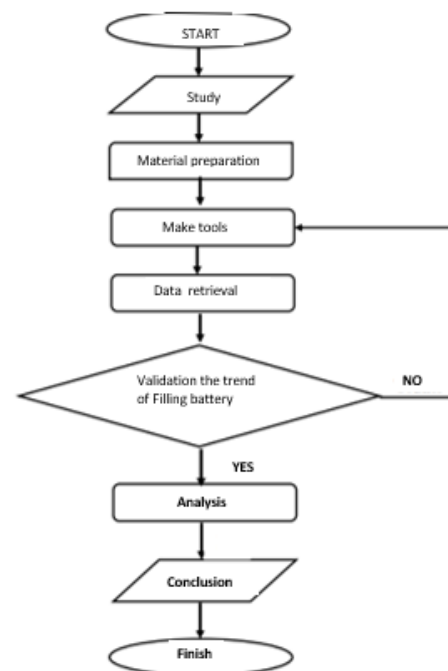


Figure 1. Research diagram

Before the testing several preparations must be completed, to ensure the accuracy and less distraction within the implication of good variables data, the preparation explains

as follows: Prepare all used equipment in data collection such as water turbines, measuring instruments, electrical circuits and others. Check all valve installations that are connected to the tendons of the H-building in ITATS to ensure that nothing is leaking. Measure the dimensions of the turbine such as the inner diameter of the runner, the outer diameter of the runner, the width of the shaft, the diameter of the shaft and the length of the shaft. Ensure all measuring instruments are in good condition (normal). Always look at the pressure on the manometer to make sure it is constant.

The next work packages are testing. In this test, the water used to drive the turbine comes from the water reservoir on the 5th floor of the H building with a water drop height of 20 m. Before entering the turbine in the pipe, some valves are attached which is used to regulate the valve opening (discharge) which will be flowed to the turbine. After the test equipment is ready, the test has to follow the instructions: Check all equipment and measuring instruments and other supporting tools that will be used in testing so that it runs smoothly. Ensure that no other installation faucets are open. Settings of all equipment to be used. Open the valve according to the variation of the valve opening, 18°, 36°, 54°, 72°, and 90°. Always look at the pressure on the manometer when you want to take data on the measuring instrument. Let it first a few seconds so that the turbine rotation is constant. Take data on pressure, rpm, voltage, and current strength

at a 12-Watt lamp load. Perform data retrieval again for all variations of the valve openings. After completing the data retrieval above, take the flow discharge data. Keep the measuring cup empty so that the research results are more accurate. Take the discharge data by filling the measuring cup to the brim and recording the time it takes to fill the 1.5-litre measuring cup.

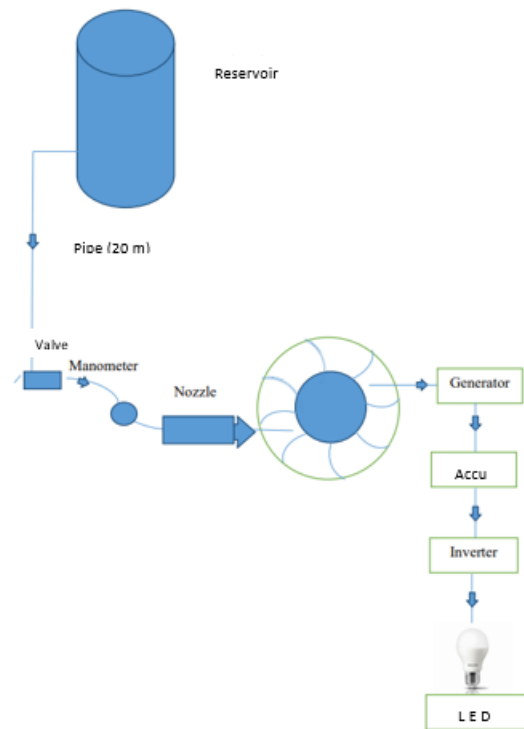


Figure 2. The system scheme

RESULT AND DISCUSSIONS

Validated Result

In general, it informed that when the opening of the valve is bigger, the rotation of the shaft is getting bigger. This condition has occurred if the valve opening is bigger which means that the resulting discharge is also large, hitting the turbine blades with great momentum, as a result, the resulting shaft rotation is also greater. So, if $H = \int r.v.dm$ is

large than H (angular momentum is also large). This research has similarities with the research conducted by [6], linearly increases in a particular direction. The difference between the method was approximately less than 10%.

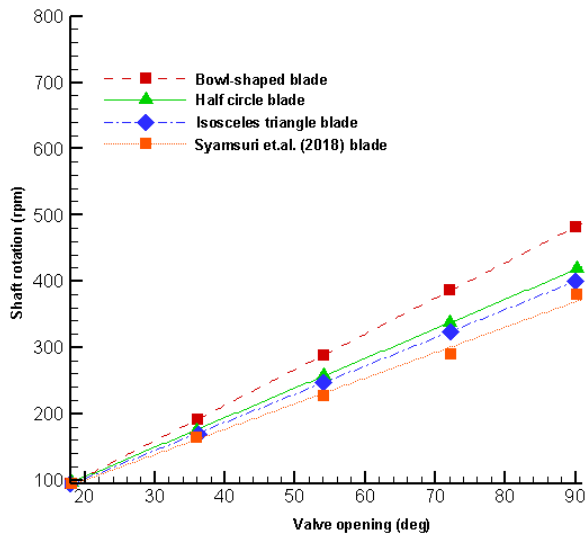


Figure 3. Describes the comparison of the effect of the valve opening on the rotation of the shaft

Relationship Between Valve OPENING VS Rpm from the Shaft Rotation

Figure 4 illustrates the comparison of the effect of the valve opening on the rotation of the shaft. In general, it can be seen that when the valve opening gets bigger, the shaft rotation is also getting bigger. This is because if the valve opening gets bigger, the resulting discharge opening is also large and hits the turbine blades with great momentum, as a result, the resulting shaft rotation is also greater. Under the formula $T = \frac{DH}{DT}$ torque equals the change in angular momentum concerning time changes [11]. The blade with the spoon type produces a higher rotation of

the shaft than other types of blades. This is due to the larger outer surface of the blade.

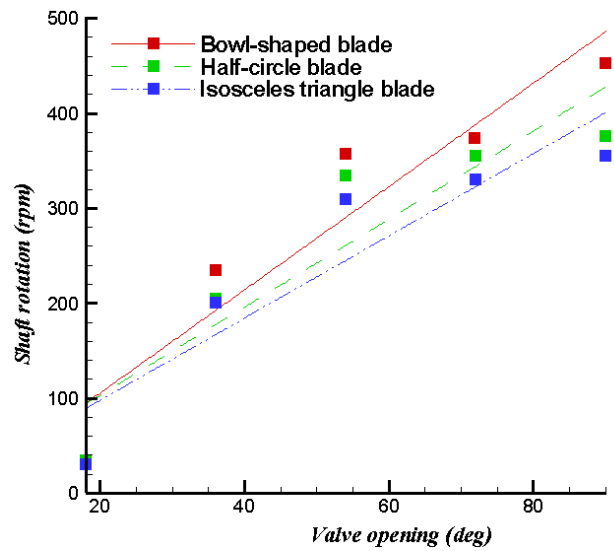


Figure 4. Effect of valve opening on shaft rotation (rpm)

The Relationship Between the Valve Opening to the Torque for the Variation of the Section of the Blade

Figure 5 describes the relationship between the valve opening to the torque with several variations of the blade section. In general, it can be seen that the larger the valve opening, the greater the torque generated. This is because when the valve is opened, the bigger the speed of the water spray hitting the turbine blade is also getting bigger, so the rotation of the turbine shaft will be even greater. Therefore, the produced energy is also getting bigger. This conforms to the torque formula:

$$T = r F \sin \theta$$

Where: T = torque (Nm), F = force (N), r = distance from the centre of mass (m) and θ = angle of flank between F and r. In the graph, it can be seen that the blade with the spoon type produces a greater torque than the type

of isosceles triangle blade and semi-circular blade.

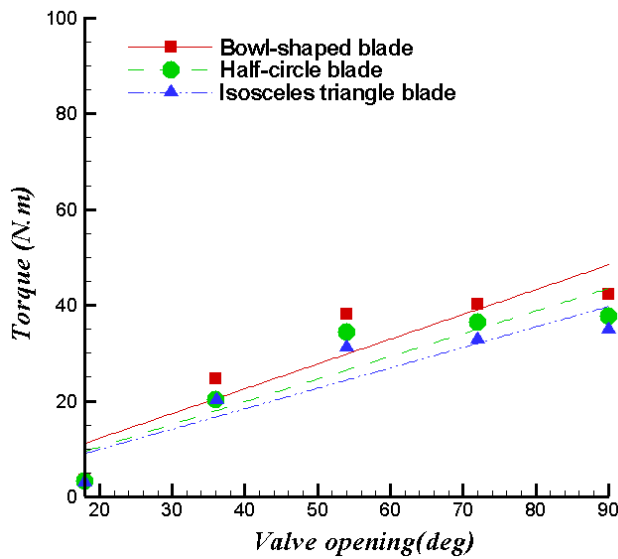


Figure 5. Relationship between valve opening and torque of different type of blade

Relation of Valve Openings to Mechanical Power for Angle Cross Section Variations

Figure 6 illustrates the effect of the valve opening on mechanical power with several variations of the blade. In general, in the figure, it can be seen that the greater the opening of the valve, the greater, the mechanical power generated. This is because when the valve is opened, the bigger turbine shaft rotation is also getting bigger. Therefore, the speed for doing work is also getting bigger. This is according to the mechanical power formula.

$$P(t) = T \cdot \omega \quad T = \frac{dh}{dt}$$

Where: P (t) = mechanical power, T = torque and ω = rpm converted to rad / s. In the graph, it can be seen that the blade with the spoon type produces a greater mechanical power than the isosceles triangle blade and the semi-circular blade.

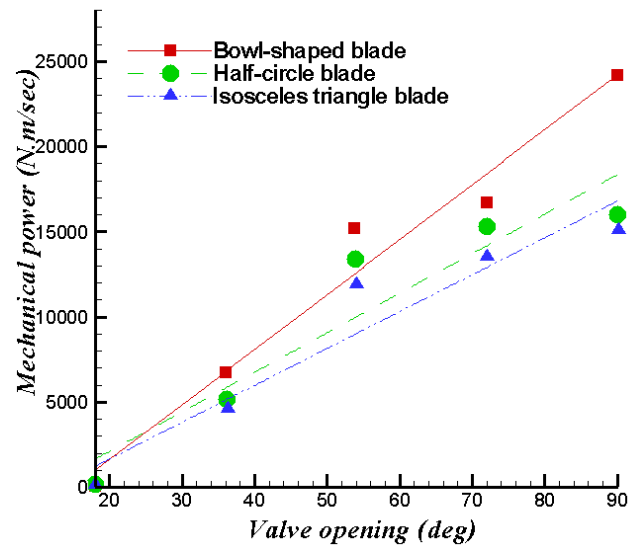
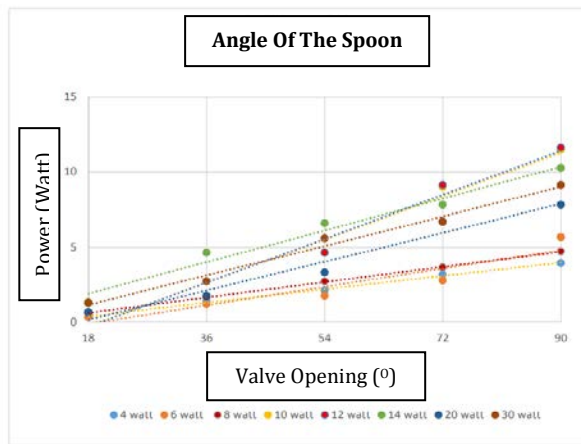


Figure 6. Effect of valve openings on mechanical power

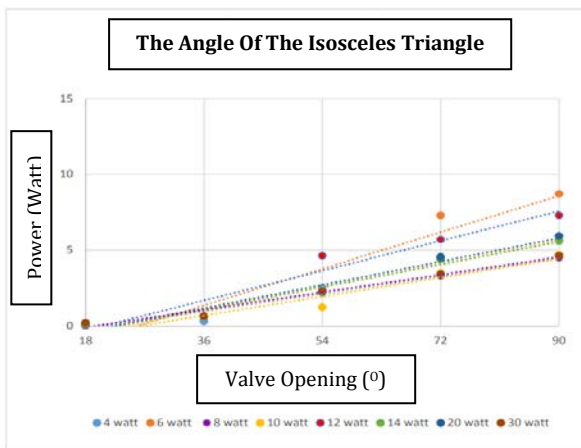
The Relationship Between Valve Openings and Electrical Power

Figure 7 is explained of the relationship between the valve opening to electric power with variations of spoon blades, isosceles triangle blades, and semi-circular blades with different lamp loads. In general, it can be seen that the greater the opening of the valve, the greater the energy produced by the electric generator and the greater the electric power produced. This is according to the electric power formula, $P = V \cdot I$ where: P = Power (Watts), V = Voltage (Volt) and I = Strong Current (Ampere). In the spoon blades, a 12 Watt lamp load produces more power than the other lamp loads. For 20 Watt & 30 Watt lamp loads produce unstable power. The isosceles triangle blade, which is the load of the 6 Watt lamp, produces more power than the other lamp loads. 14, 20 and 30 Watt lamp loads appear unstable. In the semicircular blade, the 12 Watt lamp load

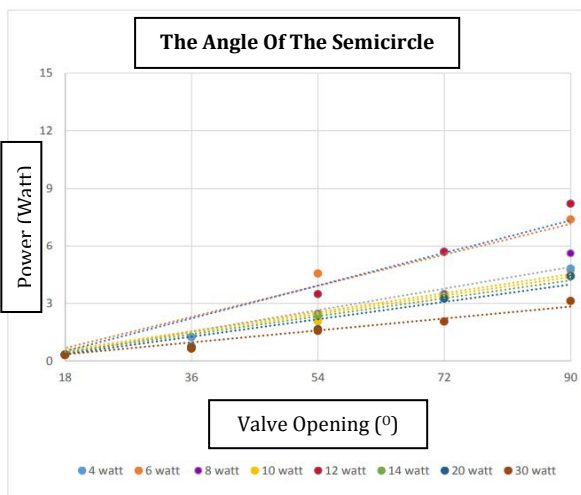
generates more electric power than the other lamp loads.



(a)



(b)



(c)

Figure 7. The relationship between the opening of the valve to the electric power, the angle of the spoon (a), the angle of the isosceles triangle (b), the angle of the semicircle (c)

CONCLUSION

The various discussions above, a conclusion can be drawn from this study that the greater the opening of the valve, the greater the electrical power is produced. This type of bowl blade produces more energy/power than half-circle blades and isosceles triangle blades. With the greater the opening of the valve, the resulting efficiency is also greater. The bowl blade types provide greater system efficiency than a half-circle blades and isosceles triangle blades. Suggestions from the authors regarding this research is not limited to collecting data, it must be completed carefully and thoroughly so that errors do not occur. This research can be continued to turn on the streetlights.

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