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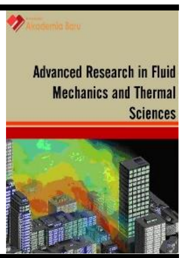

Analysis the Performance for Runner Pelton Turbine by Using Bamboo Material

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ABSTRACT

The potential of hydropower that can be utilized in Indonesia is quite abundant and cannot be utilized optimally until now. While the government has targeted the use of renewable energy in 2025 by 23% along with an emission reduction of 29% in 2030. This research is conducting experiments with the aim of analyzing the performance level of Turbine Pelton Runner rotation speed using bamboo material. The turbine design is made with two different models between square nozzle made of bamboo material and round nozzle made of copper. Results showed that bamboo material designed with a square nozzle to rotate the Turbine Pelton Runner can produce higher speed 794.4 rpm than round copper nozzle 663 rpm. Increased Turbine rotation will produce high electric energy. The potential for water discharge at the time of testing was quite large to produce electric power reaches 150 kW. The square nozzle designed from bamboo material to rotate the Turbine Pelton Runner is the latest in this article. Overall Turbine rotation performance for all three tests showed a significant improvement.

1. Introduction

The abundant renewable energy sources in the Southeast Asian region, especially in Indonesia, so far have not been able to be utilized very well [1–4]. Renewable energy which is abundant in

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Southeast Asia cannot be utilized optimally, such as hydropower, wind power, geothermal energy, biomass power and solar power [5–10]. Southeast Asian member countries have made various efforts with plans and targets for the use of renewable energy. The target was set to overcome and reduce the dependence on conventional energy which has continued to decrease in recent years [3,11].

Research through investigations on the stability of Hydro-turbines, which are used as the prime mover to produce electric power has been carried out by Liu *et al.,* [12]. Where the results are reported that the influence of non-linear hydro-turbine on the stability of HTRS can help when operating hydroelectric power plants. A total of 11 hydroelectric power projects have recently been built along the Mekong River as reported by Martinez *et al.,* [13]. The results of their research reported that the design of turbines for hydroelectric power plants could improve the ecological conditions in the region. The two main sensors used for their research functioned for the older Francis 17.5-MW turbine and the newer Francis 40-MW turbine. Three aspects: hydraulic parameters (turbine and turbine head), electrical parameters (generator speed and excitation current) and mechanical parameters (axial coordinates and axial misalignment) were analyzed with sensitivity to make the longer operation of the hydraulic turbine generator a power plant water [14]. In their research conducted to determine the various sensitivity parameters generated from the power generator that is designed. Hydropower plants can reduce overall project costs, so that many industries are interested in utilizing energy from hydroelectric power plants [15]. The results of the median nadir pressure measurements carried out in their study amounted to 74.7, 66.6, and 56.6 kPaA when operating conditions 90-, 190-, and 380-kW were carried out. An overview of the use of energy using low head micro-hydro turbines has also been discussed by Elbatran *et al.,* [16]. Where the focus of their research only focuses on the category, performance, operation, and the level of costs generated. Therefore, the utilization of energy from renewable energy sources of hydropower using the turbine drive system is very feasible to be developed. Hydropower energy is one of the renewable energy that is environmentally friendly by producing very low emissions.

The study of hydroelectric power using conventional turbines as the main driver in producing energy has been carried out by Sari *et al.,* [17]. Besides, their research also specifically discusses the pipeline system used. The topic of free surface vorticity at hydropower intakes has become a very interesting and hot issue among engineers and researchers [18]. However, the results of the review conducted mentioned that the energy of hydropower plants also has shortcomings and limitations, especially the number of water discharges generated due to erratic climate behaviour in several countries in the world. Thus, to set up and design turbines to drive electricity generators must be studied thoroughly by adjusting various constraints, especially climate change. A review of exploitation to use third-generation hydroelectric power has been carried out by Deng *et al.,* [19]. Where the results of the review conducted in their paper, which aim to find out the level of water discharge for electricity generation in the Congo River. Based on the analysis of studies conducted that the Congo River is very suitable for the development of hydroelectric power plants.

Research by utilizing the turbine as a prime mover to produce hydroelectric energy in several countries has been widely carried out including Indonesia. However, the development of hydropower energy to date and the future is still very much needed. This is in line with fossil energy, which continues to experience depletion at higher prices and hydropower energy. One of the renewable energy sources that are abundant enough to be utilized in reducing dependence on fossil energy. The main topic of discussion specifically carried out in this study is to analyze the performance of the Pelton runner turbine that is used as a driving force to produce electrical energy.

2. Material and Methodology

Specifically, the Pelton turbine used in this study is fully shown in Figure 1. The rotation of this turbine aims to provide optimum working methods for relatively high water headings. The high impulses are obtained at speeds from the height of the water using the nozzle. Theoretically, the velocity of water jets from the nozzle, C1 is: C1 = √2.g.H. However, this speed will be reduced due to the contractual venous effect that occurs in the nozzle outlet [20].

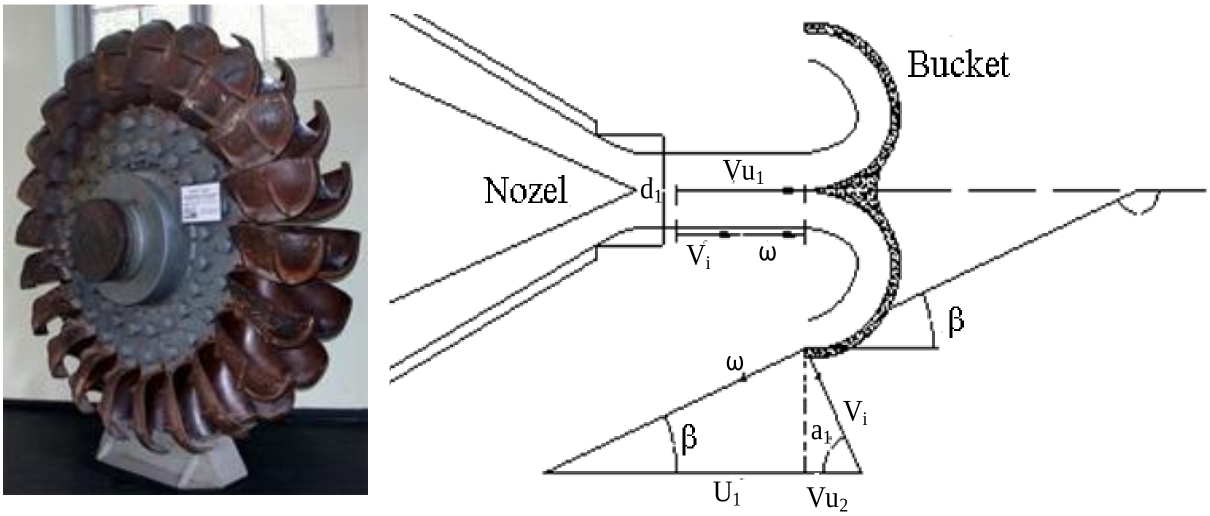

Fig. 1. Pelton turbine wheel and water speed triangle

Two main factors determine the availability of power potential at a location that has hydropower potential [21].

i. The volume of water flow/discharge Q in units of litres/second or m^3/s.
ii. Head H waterfall height with units of meters.

With the known Q water flow and H waterfall height, the water potential power (Pf) can be calculated by the equation below [21].

$$Pf = \rho \times g \times Q \times H \quad (1)$$

With: *Pf* = Potential of hydropower (W)
ρ = Density of water (1000 kg/m^3)
g = Earth's gravity speed (9,81 m/s^2)
H = High water fall (m)
Q = Flow discharge (m^3/s)

Water discharge is the volume of water that passes through a cross-section each time unit. The amount of discharge can be determined using the continuity equation below [21].

$$Q = Cd \, . \, be \, (2g.he^3)^{1/2} \quad (2)$$

With: *Cd* = Discharge coefficient
be = The width of water spills from the width of the dam (m)
he = The height of water spills from the height of the dam (m)

The procedure for designing and building a Pelton Turbine prototype is explained in this section. The main parts are designed, such as turbine wheels (runners), blades (buckets), nozzle (nozzle). Furthermore, tools have been strung together to make bearings and are installed by connecting to the generator. Turbine wheels made of wood are arranged and made in a circular pattern. On the outside of the wheel is made a slot as a holder of blades that are ready to be assembled. Solid iron shaft-mounted (*fix*) at the centre of the turbine wheel with an intermediate coupling connected to the generator. The Pelton Turbine testing system procedure designed in this study is shown in Figure 2.

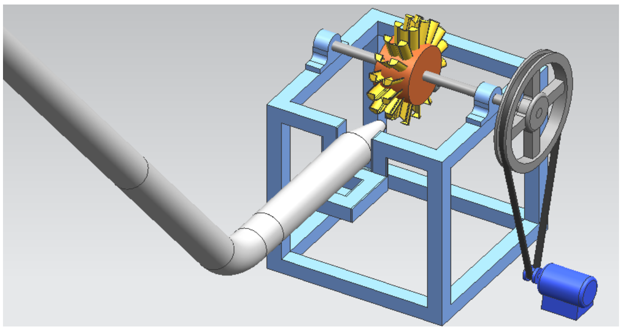
Fig. 2. The flow of Pelton Turbine Testing Systems

3. Results and Discussion

3.1 Pelton Turbine Testing System Flowchart

Water from the pump enters the intake pipe directly to the gate valve and continues to the nozzle and at the nozzle, a pressure gauge has been installed to measure the water pressure, which is then converted to determine the effective heat that enters the turbine. Water from the turbine is discharged through a drain (tailrace), which is just below the turbine, and flows again into the reservoir and continues to enter the suction pool to be recirculated with a pump. The flow of the Pelton Turbine testing system in the Turbine Test Installation, Department of Mechanical and Industrial Engineering, Faculty of Engineering, Gadjah Mada University, Yogyakarta can be seen in Figure 3.

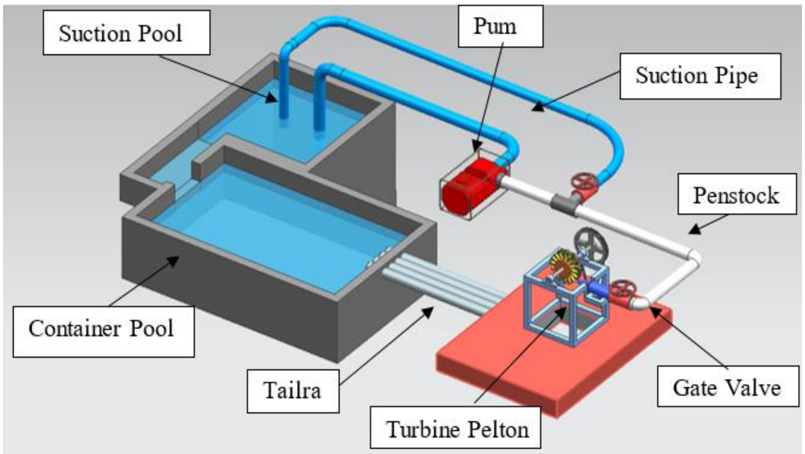

Fig. 3. Pelton Turbine Testing System Flowchart

3.2 Measuring Results of Square and Round Nozzle Turbine

Tests carried out directly based on designs that have been made using a tachometer. The results of the first analysis carried out in this research paper were to determine the turbine rotation rate before being given a load for the square nozzle Figure 4. Test results show that the greater the valve opening provided, the higher the turbine rotation produced. Therefore, the higher the rotation, the greater the electrical energy output obtained. From the results of testing, three times the treatment shows that the electrical power produced shows a significant increase from testing one, two and three. The more optimal turbine rotation speed during operation, the electric energy generated increases. However, the turbine rotation is also very dependent on the existing water discharge. The highest rounds of Turbine produced for each test were 576, 764.2 and 794.4 rpm, respectively.

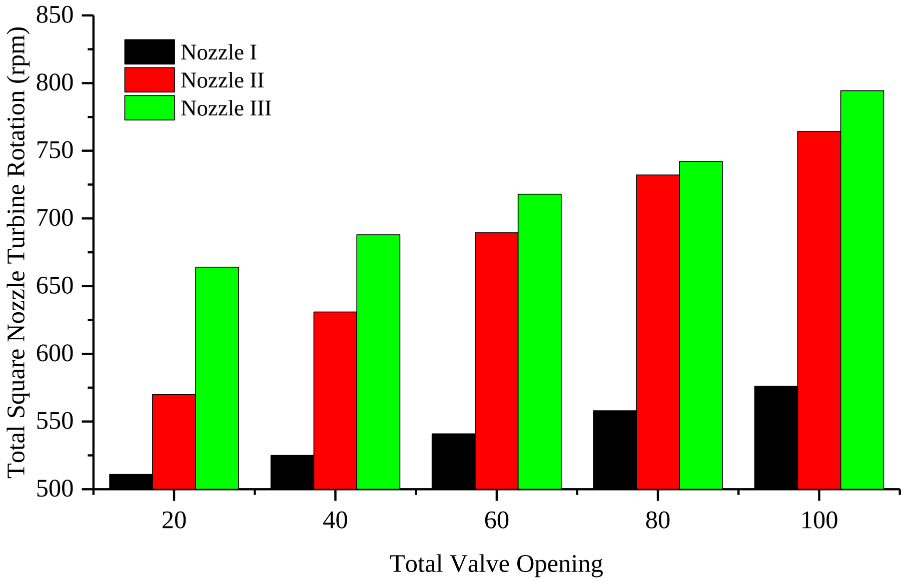

Fig. 4. Total of Square Nozzle for Different Valve

Furthermore, an experiment was carried out to determine the performance and level of the turbine spin with a round nozzle. Based on the analysis results when testing using a round nozzle turbine shows a little lower than when testing using a square nozzle turbine. Tests at this stage also use three tests with five different valve openings Figure 5. From the test results, it can be reported that the rotation of the turbine with the round nozzle of the turbine speed trend shows a significantly similar increase when using a square nozzle turbine. However, the turbine speeds produced were lower by 492, 623 and 663 rpm respectively for the first, second and third tests. Thus, the turbine rotation with the two tested nozzles shows a significant upward trend. With the increase in turbine rotation produced, the electrical energy released will also be even greater. The design of the square nozzle to increase the rotation of the Pelton Runner Turbine is a renewal of this work.

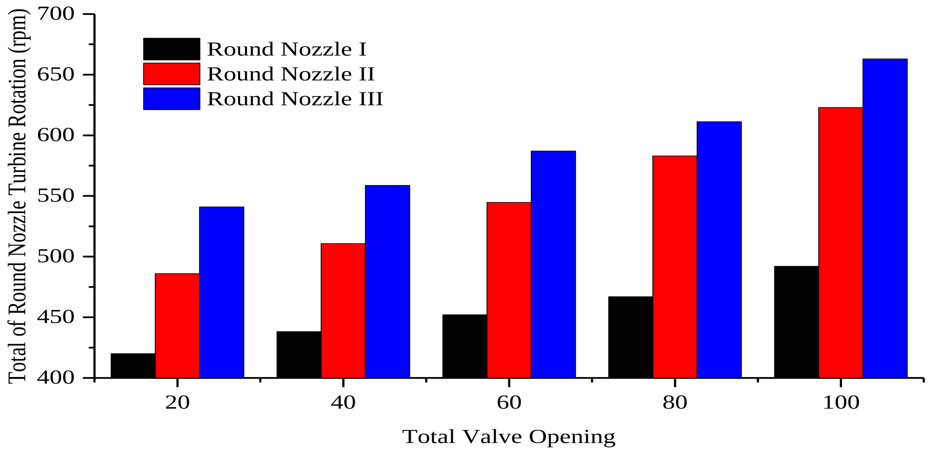

Fig. 5. Total of Round Nozzle Turbine Rotation for Different Valve

Figure 6 shows the amount of water discharge available at the time the experiment was carried out. Where the increasing amount of water discharge that comes out with a larger valve opening. The valve opening tested in the research paper aims to maximize the amount of water discharge by adjusting climate conditions, especially during the dry season. With this design, the turbine rotation and the energy produced will remain optimal. When the rainy season comes, automatically the amount of water discharge will increase so that the valve opening is opened to the maximum. This is done to keep the designed water reservoir from being damaged or broken because of too much water. The results of research using the Pelton Turbine that can produce electricity by 10% -25% have also been carried out by Zeng *et al.,* [22]. However, their research was carried out with simulations using different prototype four-nozzle Pelton turbines. Modelling by applying a jet-runner interaction system in various operating conditions for electric energy builders using the Pelton Turbine has been discussed by Anagnostopoulos *et al.,* [23]. Furthermore, their research optimizes the numerical design of the bucket shape using stochastic optimizers based on evolutionary algorithms. The results of the design carried out can produce Pelton Turbines for hydroelectric power by 150 kW.

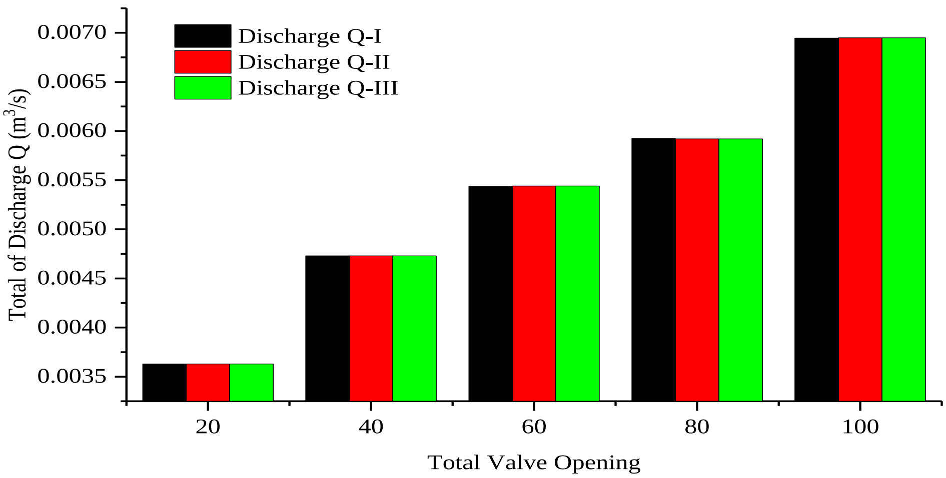

Fig. 6. Total Measurements of Discharge Q for Different Valve

Discharge parameter Q-I, Q-II and Q-III is the amount of water release from the three tests carried out in this study. Meanwhile, the m^3/s unit is the amount of water that occurs in each test carried out. In this experiment using five-valve openings from the three tests. The valve openings in each test are given at 20%, 40%, 60%, 80% and 100%. This is done to determine the results of the electrical energy produced with the amount of water present in each experiment.

3.3 Measurement of Water Energy Potential Power

The construction of Pelton Runner Turbines for power plants requires the amount of water available when it is carried out at a designated place. Potential enough water discharge will normalize the Turbine operation to be built. The potential for water discharge carried out in the study is very potential and sufficient to generate more 150 kW of electrical energy. Therefore, the construction of a hydroelectric power plant (PLTA) is designed to use as many as five different valve openings. This is designed to maximize the flow of water to turn turbines and the electrical energy generated remains optimal. The amount of water that can be generated to open the valve 100% reaches 0.006946 (m^3/s) with the amount of potential energy generated at 622.90545 (watts) Figure 7 and 8. With sufficient water potential, it is possible to increase the energy generated from the power plant that has designed this. Water Discharge - I, II and III was established as parameters for all three tests. In each test, valve openings are given at 20%, 40%, 60%, 80% and 100%. Meanwhile, m^3/s used in this stage is the amount of water released from each given valve opening.

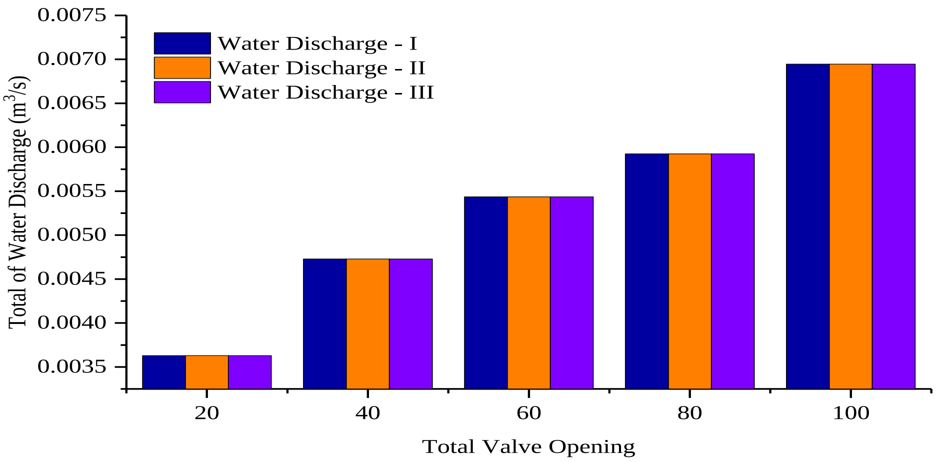

Fig. 7. Total Measurement of Water Discharge for different Valve

Finally, the analysis conducted in the study reported that the water discharge rate generated in the study showed differences in each of the tests performed Figure 8. This difference is due to the different designs between square nozzles and round nozzles. When testing using a square nozzle, the amount of water discharge is higher than when testing with a round nozzle. The use of material with pure round nozzles uses copper obtained from the company that supplies turbines. While the material for the design uses a square nozzle made of bamboo, thus this is what distinguishes the output of the water discharge to rotate the turbine. Therefore, the results of the square nozzle design conducted in this study are the latest in the discussion in this research paper.

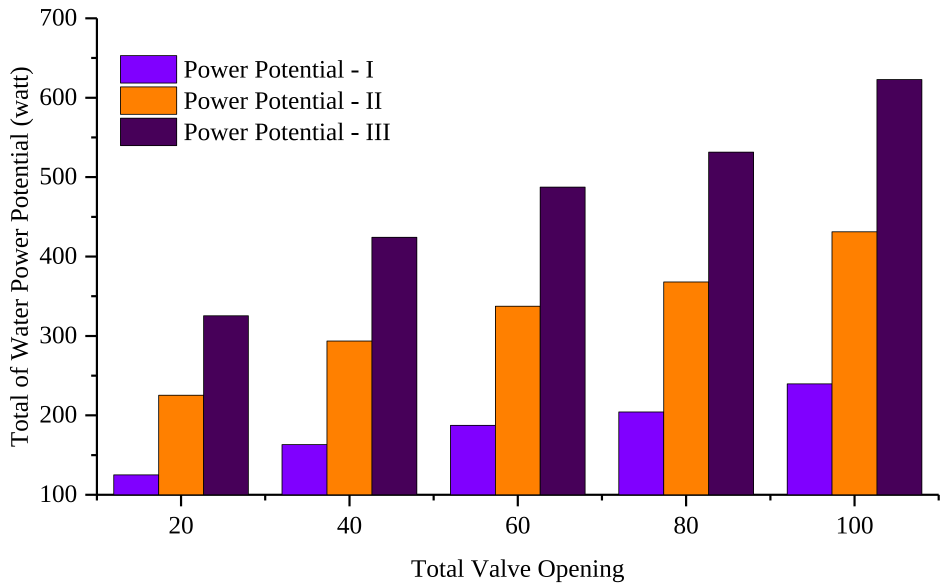

Fig. 8. Total Measurement of Power Potential (watt) for Different Valve

4. Conclusions

Three trials tests were carried out in this research paper, these trials are divided into five-valve openings. Analysis results of the experiments using the Pelton Runner Turbine to drive the power plant can be drawn as follows

i. The rotation speed of the Square Nozzle Turbine produced for the first test was 511 rpm, lower than the second and third tests for valve opening by 20%.
ii. The rotation speed of the Round Nozzle Turbine at the valve opening is 20% for three trials of 420 rpm, 486 rpm and 541 rpm, respectively.
iii. While the experimental results using a round nozzle material is lower than the square turbine material.
iv. The electrical energy produced three times of the experiment is 239 watts, 431 watts and 622 watts, respectively.

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