Analysis of the Effect of the Number of Valve Openings on the Performance Value of the Pelton Turbine Prototype

Sandra Mayang Dika Ridwan[1], **Alfian Ady Saputra**[2*],
[1]*Program Studi Teknik Mesin, Universitas Pamulang, Tangerang Selatan, 15417, Indonesia*
[2] *Program Studi Teknik Mesin, Universitas Pamulang, Tangerang Selatan, 15417, Indonesia*
**Email Corresponding Author:* alfianadys@gmail.com

ABSTRAK

Turbin Pelton merupakan salah satu jenis turbin impuls yang memanfaatkan pancaran air bertekanan tinggi melalui nozzle untuk memutar sudu. Salah satu factor yang memengaruhi kinerja turbin adalah bukaan katup, karena besar kecilnya bukaan katup akan menentukan debit air yang mengalir ke turbin. Penelitian ini bertujuan untuk menganalisis pengaruh jumlah bukaan katup terhadap performansi prototype turbin pelton. Metode yang digunakan Adalah eksperimen pengaruh jumlah bukaan katup yang menghasilkan perbedaan debit air, kemudian diukur torsi, daya turbin, dan efisiensi yang dihasilkan. Pengujian dilakukan pada beban tetap 1 kg dengan jumlah sudu 12 buah. Hasil penelitian menunjukkan bahwa torsi maksimum yang diperoleh adalah 0,2695 Nm. Daya air tertinggi sebesar 9,45 W, dan efisiensi maksimum dicapai pada debit 26 LPM dengan bukaan katup yang menghasilkan diameter efektif nozzle 9-11 mm, yaitu sebesar 90,97-91,38%. Efisiensi terendah terjadi pada bukaan katup yang setara dengan diameter nozzle 9 mm, yaitu 22,15%. Hasil ini menunjukkan bahwa jumlah bukaan katup berpengaruh signifikan terhadap performansi turbin pelton, terutama pada parameter efisiensi dan daya keluaran.

Kata kunci: Jumlah *Nozzle*; Pervormansi Turbin Pelton; Variasi Diameter.

ABSTRACT

The Pelton turbine is a type of impulse turbine that utilizes a high-pressure water jet through a nozzle to rotate the turbine buckets. One factor influencing turbine performance is the number of valve openings, as the opening size determines the water flow rate directed to the turbine. This study aims to analyze the effect of the number of valve openings on the performance of a Pelton turbine prototype. The research method employed is an experimental approach by varying the valve openings, resulting in different water flow rates, followed by measurements of torque, water power, turbine power, and efficiency. The tests were conducted under a constant load of 1 kg with 12 buckets. The results show that the maximum torque obtained was 0.2695 Nm. The highest water power of 15.41 W occurred at a flow rate of 30 LPM, while the lowest water power of 10.03 W was recorded at the smallest flow rate. The highest turbine power was 9.45 W, and the maximum efficiency was achieved at a flow rate of 26 LPM with valve openings producing an effective nozzle diameter of 9–11 mm, reaching 90.97–91.38%. The lowest efficiency was observed at a valve opening equivalent to a 9 mm nozzle diameter, at 22.15%. These findings indicate that the number of valve openings has a significant effect on Pelton turbine performance, particularly in terms of efficiency and output power.

Keywords: Diameter Variation; Number of Nozzles; Pelton Turbine Performance.

INTRODUCTION

Electrical energy is the main human need, used to operate various equipment, furniture, and systems that support daily activities [1]. Along with the times, the demand for electrical energy continues to increase, so the availability of reliable electricity supply is an important factor in supporting the economy [2]. In the midst of this high demand, the use of fossil energy as the main source of power generation still dominates in Indonesia, even though the country has abundant water resource potential. [3].

Hydroelectric Power Plants (PLTA) are one of the renewable energy solutions that are environmentally friendly and only cause little pollution if managed properly [4]. In hydropower systems, water turbines play an important role in converting the potential energy of water into mechanical energy, which is then converted into electrical energy by generators [5]. One type of turbine that is widely used, especially in locations with large water drop height (*head*) and relatively small discharge, is the pelton turbine [6].

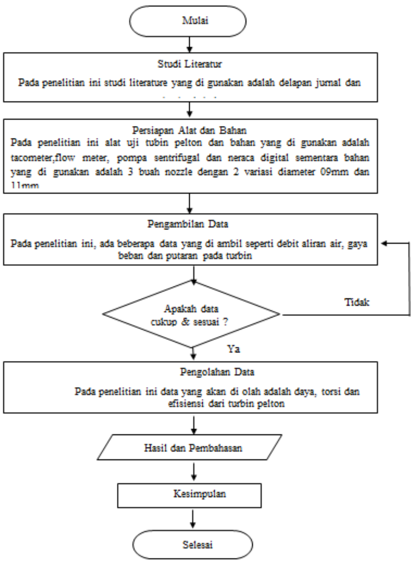
Pelton turbines work on the principle of utilizing high-speed water jets directed through nozzles to the *turbine* bucket [7]. The kinetic energy of the water flow generates an impulse force that spins the turbine wheel [8]. One of the essential components in the operation of a pelton turbine is the valve that regulates the flow opening to the nozzle [9]. The small size of the valve opening affects the incoming water discharge, thus affecting the output power torque, and turbine efficiency [10].

Adjusting the number of valve openings is a crucial factor to optimize turbine performance [11-12]. Variations in valve openings can change the water discharge directed to the spoon, which ultimately affects the energy conversion efficiency [13]. Therefore, experimental research is needed to analyze the effect of the number of valve openings on the performance of the pelton turbine.

The research was conducted using a laboratory-scale prototype pelton turbine, which allows testing under controlled conditions. Through valve opening variations, parameters such as torque, water power, turbine power, and efficiency are measured. The results of the study are expected to provide empirical data that is useful in the development of efficient pelton turbine designs and in accordance with existing operational conditions.

RESEARCH STAGES

This study uses laboratory experimental methods to analyze the effect of the number of valve openings on the performance of the prototype pelton turbine. The test was carried out at the Mechanical Engineering laboratory of Pamulang University PSDKU Serang under controlled conditions.



Gambar 1 Diagram Alir Penelitian

RESEARCH METHODS

In this study, equipment consisting of several main instruments that complement each other was used. The set of tools serves to support the testing and data collection process accurately. The equipment is as follows :

1. Flow Meter

Gambar 2 *Flow meter*

2. Taco Meter

Gambar 3 *Taco meter*

3. Pompa Sentrifugal

Gambar 4 Pompa sentrifugal

4. Neraca Digital

Gambar 5 Neraca Digital

The research materials that will be used are 3 *nozzles* with 2 variations, namely 3 *nozzles with* a diameter of 9 mm, and 3 nozzles *with* a diameter of 11 mm.

Gambar 6 Nozzle

To perform the analysis on a pelton turbine the following mathematical equations are used:

1. Nozzle tip cross-sectional area (A)
   To calculate the area of the nozzle tip that mashes the turbine spoon is:
$$A = \frac{1}{4}\pi d^2$$
2. Flow speed (V)
   Flow rate is calculated using the equation :
$$V = \frac{Q}{A}$$
3. Mass flow rate ($\dot{m}$)
   The mass flow rate is calculated using the formula:
$$\dot{m} = \rho . Q$$
4. Water Power (P_a)
   The power of water can be calculated using the equation
$$P_a = \frac{1}{2}\rho . A . V^3$$
5. Angular speed (ω)
   To obtain the value of angular velocity an equation is used:
$$\omega = \frac{2.\pi.n}{60}$$
6. Turbine power
   Turbine power is calculated using the equation:
$$P_t = T . \omega$$
7. Turbine efficiency
   The turbine formula can be calculated using the equation:
$$\eta_t = \frac{P_t}{P_a} . 100\%$$

RESULTS AND DISCUSSION

In the discussion, the effect of the number of valve openings on turbine power and efficiency is reviewed from the difference in nozzle diameter used. Where the diameter of the nozzle is compared to 9 mm and 11 mm can be described in table 1.

Tabel 1 Performance value (P_a, P_t, dan η_t) based on valve openings (Q)

Perbandingan Performansi Diameter Nozzle Vs Jumlah Katup

pada Q = 26 LPM

Katup	Daya Turbin (watt)		Eff. Turbin (%)	
(bh)	Dia. Noz. 9 mm	Dia. Noz. 11 mm	Dia. Noz. 9 mm	Dia. Noz. 11 mm
1 katup	9,17	4,09	91,38	90,97
2 katup	4,76	3,59	47,43	79,87
3 katup	3,31	3,18	32,98	70,71

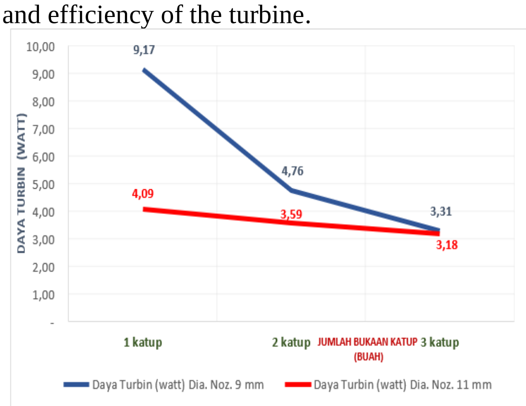
pada Q = 28 LPM

Katup	Daya Turbin (watt)		Eff. Turbin (%)	
(bh)	Dia. Noz. 9 mm	Dia. Noz. 11 mm	Dia. Noz. 9 mm	Dia. Noz. 11 mm
1 katup	9,31	4,51	74,29	80,37
2 katup	4,76	3,81	37,98	67,81
3 katup	3,29	3,33	26,27	59,28

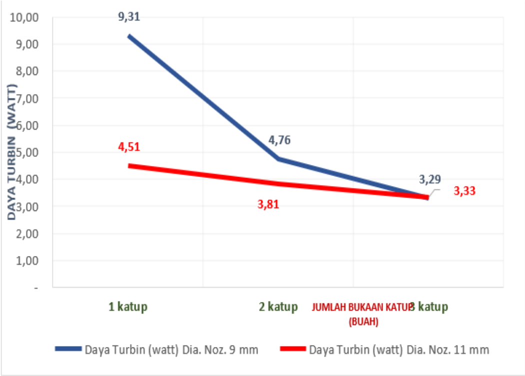
pada Q = 30 LPM

Katup	Daya Turbin (watt)		Eff. Turbin (%)	
(bh)	Dia. Noz. 9 mm	Dia. Noz. 11 mm	Dia. Noz. 9 mm	Dia. Noz. 11 mm
1 katup	9,45	4,74	61,31	68,61
2 katup	5,05	4,12	32,76	59,63
3 katup	3,41	3,48	22,15	50,40

The test results show that the variation of valve openings has a significant effect on the performance of the pelton turbine. Changes in valve openings change the water discharge entering the *nozzle*, affecting the torque, power, and efficiency of the turbine.



(a)



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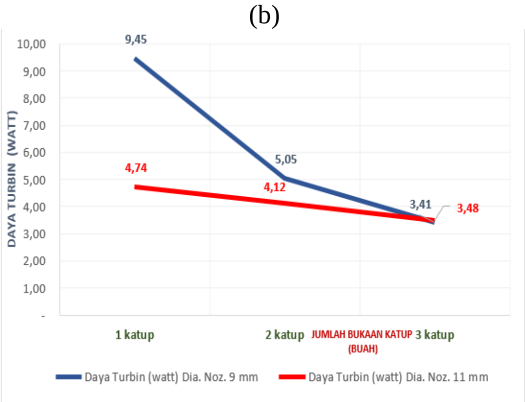
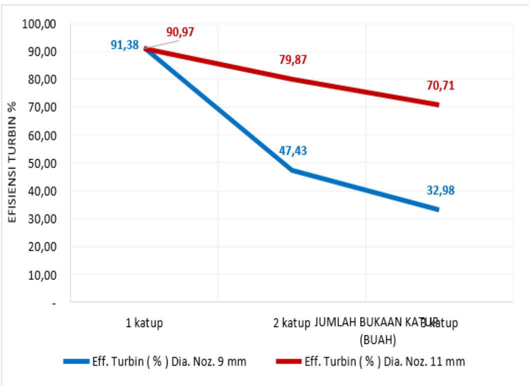


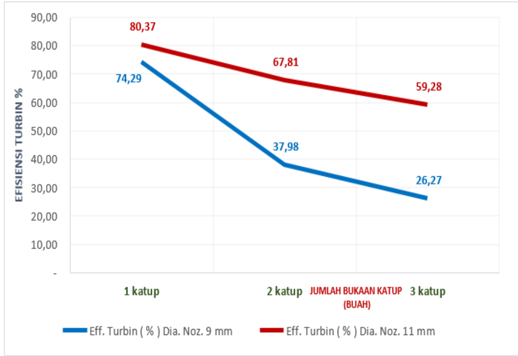
(c)

Figure 7 Graph of the relationship of valve opening variation to turbine power at 9mm and 11 mm nozzles at: (a) 26 LPM discharge; (b) 28 LPM discharge; (c) 30 LPM discharge.

Based on Table 1 and figures 7a-7c, it can be seen that turbine power tends to decrease as the number of valve openings increases, although the available water power is relatively constant at each test discharge. This can be explained through the principle of impulse that is, the larger the valve opening, the less focused the flow of water coming out of *the nozzle* so that the momentum transferred to the turbine blade is reduced. This condition leads to a decrease in effective torque generated by the turbine, despite the higher water discharge.



(a)



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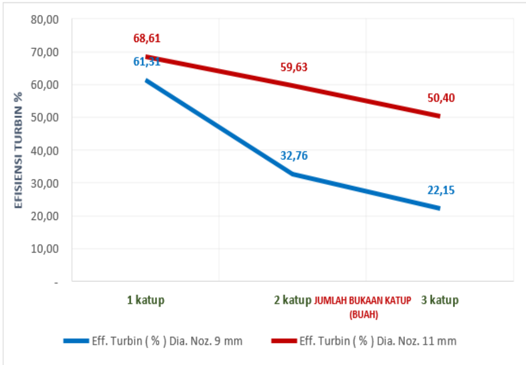

(c)

Figure 8 Graph of the relationship of valve opening variation to turbine efficiency in 9mm and 11 mm nozzles: (a) 26 LPM discharge; (b) 28 LPM discharge; (c) 30 LPM discharge.

The highest turbine power was recorded at 9.45 W at one valve open with a discharge of 30 LPM using *a* 9 mm diameter nozzle. On the other hand, the lowest turbine power only reached 3.18 W at a three-valve opening with a discharge of 26 LPM using *an 11 mm diameter* nozzle .

A similar phenomenon can be seen in efficiency results. In Figure 8a-8c, it appears that the maximum efficiency occurs at a discharge condition of 26 LPM, which is 90.97-91.38% for *nozzles* with a diameter of 9mm and 11 mm with one valve open. This condition indicates that at small valve openings, the kinetic energy of the water is more concentrated so that the impact force against the blade is more optimal and the energy can be converted more efficiently. However, when the number of valves is enlarged, the efficiency actually decreases drastically to reach the lowest value of 22.15% at the opening of three valves with *a* nozzle diameter of 9mm. This decrease in aficionance shows that overly dispersed water flow reduces the effectiveness of converting kinetic energy into mechanical energy.

CONCLUSION

Based on the results of testing and analysis, the number of valve openings has been proven to have a significant effect on the performance *of* the prototype pelton turbine. Larger valve openings increase water discharge, resulting in higher torque, water power, and turbine power. Maximum efficiency is achieved at 26 LPM discharge with valve openings resulting in an effective *nozzle* diameter of 9-11 mm, which is 90.97-91.38%. The lowest efficiency is obtained at the valve opening equivalent to a nozzle diameter of 9 mm, which is 22.15%.

These results show that proper valve opening settings are critical to optimizing the efficiency and output power of the pelton turbine. These findings can be used as a reference in the design and operation of pelton turbines, both on a laboratory scale and in field applications so that the performance of energy conversion systems can be maximized.

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