Performance of Pelton Turbine for Hydroelectric Generation in Varying Design Parameters

N Kholifah*, A C Setyawan, D S Wijayanto, I Widiastuti and H Saputro

Department of Mechanical Engineering Education, Sebelas Maret University, Surakarta, Indonesia.

*nurkholifah@student.uns.ac.id

Abstract. Water power is a renewable energy source which has great potential in replacing fossil energy for generating electricity. The aim of this research is to analyze the influence of vertical distance of water source (water head) and nozzle diameter on the electrical power generated by Pelton turbine. It used Pelton turbine type with 22 buckets (vanes) which employed a PMG 200 watts generator with 1 : 2 pulley transmission system. Four different values of nozzle diameter and three different values of water head were chosen as the design parameters of the turbine. The electrical power was measured in three replications for each combination of the design parameters. The research showed that water head and nozzle diameter significantly affect the power generated by the Pelton turbine. The higher the water head from the surface, the more power generated. It was found that the electric power linearly increases with the increasing of nozzle diameter. However, it reaches the peak in 9 mm nozzle diameter and is getting lower in a larger diameter. The highest electric power of 16.89 watt is observed by adjusting the water head on 4.6 m with 9 mm nozzle diameter. Those design parameters are able can produce a rotation speed at 320 rpm in the generator. By identifying the appropriate parameters, it is possible to have more power generated by the water turbine used for hydroelectric power generation plant.

1. Introduction

The use of renewable energy sources gains more focus of attention considering the increasing concern in negative environmental effects of conventional sources of energy. In fact, Indonesia is a country which has plenty of renewable energy resources as shown in Table 1. However, it can be seen that the installed capacity of the renewable energy sources for generating electrical power is less than 6.8% from total resources available [1].

Table 1. Potential of National Renewable Energy

Renewable energy	Resource	Installed capacity
Hydro Power	75.67 GW	4,200 MW
Geothermal	27.00 GW	800 MW
Bio Mass	49.81 GW	302.40 MW
Solar	4.80 KkWh/m^2/day	8.00 MW
Wind Turbin	9.29 GW	0.50 MW
Nuclear Power	24.112 TON = 3 GW	

As seen in Table 1, hydropower is the greatest potential of energy resources which capable to generate 75.67 GW of electrical energy. The micro-hydro electric generation is a small-scale power plant producing less than 200 kW electrical powers [2]. In general, there are two types of turbines used for micro-hydro:

1. Action turbine (impulse turbine) for example, Pelton turbine
2. Reaction turbine, for example Francis turbine (radial type) and Kaplan turbine (axial type)

As an axial flow turbine, the water flows in the blade of Pelton turbine from the reservoir to the penstock in which the lower end of the penstock is connected to the nozzle. The nozzle is used to increase the jet speed, while the blade is used to make the runnerrotates. The angle is mounted on the edge of the runner while the runner itself is mounted on the shaft. The turbine shaft is connected to the generator shaft, where the generator works to convert the rotation produced by the turbine into electrical energy [3].

There are several factors that may affect the power and efficiency of a Pelton model turbine, such as nozzle diameter, nozzle number, blade shape, the blade number, and water head [4]. In this work, the performance of Pelton turbine under different geometries and water head is studied to determine the most effective operation parameters.

2. Methods

This experimental study used a Pelton turbine as specified in Table 2 by varying nozzle diameter and water head.

Table 2. Pelton Turbine Specifications

Specifications	Values
Diameter of Bucket	70 mm
Number of Buckets	22
Runner Diameter	D 300 mm
Shaft Diameter	20 mm
Diameter of Casing	1320 mm
Pulley Transmission Ratio	1 : 2
Material Bucket	*Stainless steel*
Generator	A permanent magnet AC generator capacity of 200 watts

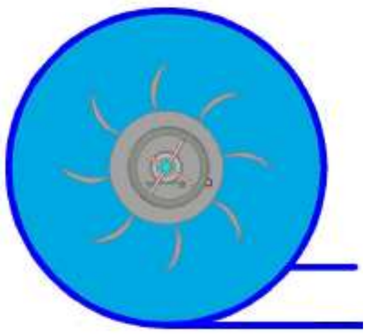

Figure 1. Micro-hydro Pelton Turbine

The performance of turbine is represented by the electrical power generated [5]. The experiment was conducted in the water turbine with varying nozzle diameter, of 5 mm, 7 mm, 9 mm and 11 mm placed in different levels of water head of 3.6 m and 4.6 m. The experiment was conductedusing configurationas presented in Figure 2.

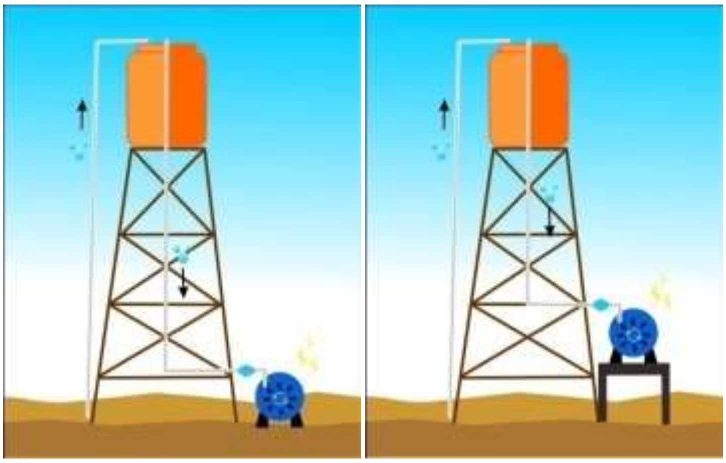

Figure 2. Pelton Turbin Testing Scheme

3. Results and discussion

3.1 Flow rate of water

The water flows through the nozzle and is directed into the blades of a turbine runner which then creates a force to generate electricity power [6][7]. It was observed that the flow rate of water varied with different geometries and water head. It can be seen from Table 3 that the flow rate linearly increases with increasing of nozzle diameter as well as the water head.

Table 3. Flow Rate of Water Through Various Nozzle Diameters

Flow rate(m^3/s)				
Nozzle (mm) / ***Head (m)***	5	7	9	11
3,6	0,38 x 10^{-3}	0,5 x 10^{-3}	0,85 x 10^{-3}	0,97 x 10^{-3}
4,6	0,41 x 10^{-3}	0,53 x 10^{-3}	0,88 x 10^{-3}	1 x 10^{-3}

3.2 Speed of rotation and electrical power

The rotational speed and electrical power generated are presented in Figure 3 to 5. It is clearly seen from those figures that the water head affects the electrical power generated. The 4.6 m water head produces higher rotational speed in the generator compared to the 3.6 m head (Figure 3). The rotational speed also increases with increasing of nozzle diameter. However, it reaches the peak of 320 rpm for 4.6 m water head at 9 mm diameter nozzle and tends to decrease with increasing of diameter.

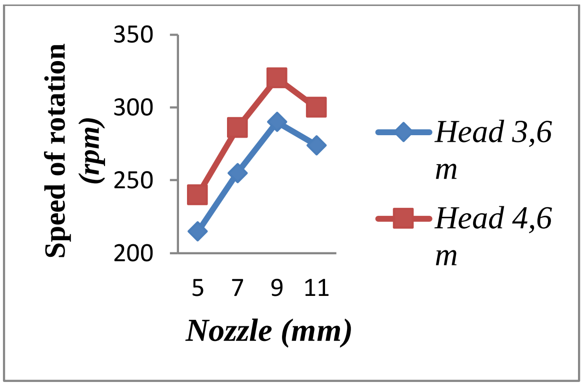

Figure 3. Rotational Speed with Nozzle Diameter

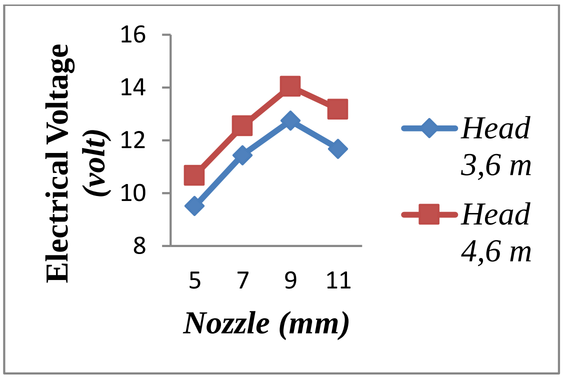

Figure 4. Eletrical Voltage Generated with Nozzle Diameter

In Figure 4 and 5, the trend of electrical voltage and power are similar with the rotational speed of the electricity generator. The maximum electrical power generated is 16.89 watts by using operational parameters of 4.6 m water head and 9 mm nozzle diameter.

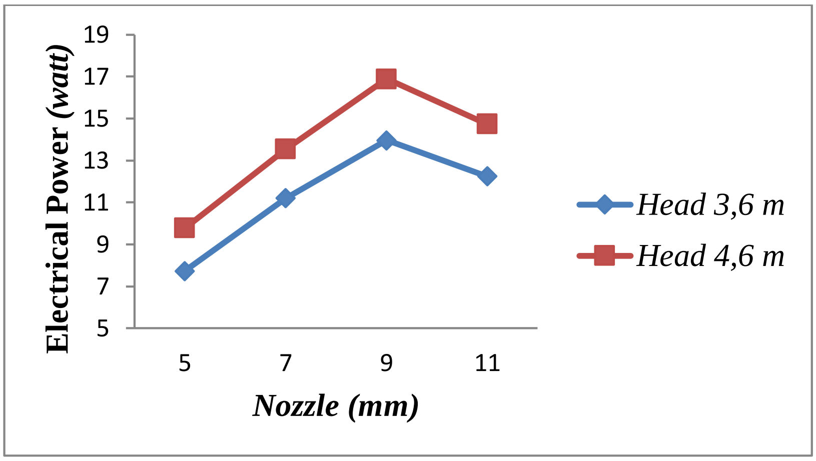

Figure 5. Relationship of Electricity Power to Nozzle Diameter

The larger nozzle diameter will drain more fluid and create higher flow rate which rotates the Pelton turbine. This higher rotation in the generator will produce higher electric power. However, there is an optimum size of the nozzle diameter since an excessive diameter size will have less water pressure. A nozzle is applied to produce water pressure in rotating the turbine. The dimension of the nozzle should be carefully considered based on the available water head to produce the required electric power generated [8].

4. Conclusion

The increase of electric power generated by the generator is proportional to the available water head. In contrast to the head, the nozzle diameter variation increases in the resulting electric power but decreases the power in the 11 mm diameter nozzle. Highest electric power is generated at 9 mm diameter nozzle and 4.6 m head, which is 16.89 watts. While the smallest electric power generated by the variation of 3.6 m head with 5 mm nozzle variation of 7.73 watts.

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