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ANALYSIS OF NOZZLE AND HEAD DIAMETER VARIATION TOWARDS PELTON TYPE MICROHIDRO OUTPUT POWER

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KEYWORDS

Micro-hydro
Pelton turbine
Head
nozzle diameter
simulation
electric power

ABSTRACT

Microhydro is a eco-friendly power plant for output capacity below 100 KW. Its simple construction and relatively inexpensive design costs are the reason why microhydro is more suitable to be used as a source of electrical energy, especially in isolated areas that are still difficult to reach by electricity of PLN. There are several factors that affect the output power of Pelton microhydro, such as volume flow rate, number of bucket, bucket shape, runner diameter, head, number of nozzle, and nozzle diameter. The head and diameter of the nozzle are the variables in this research. The purposes is to analyze the influence of head variation and nozzle diameter to the electrical power produced by Pelton turbine from simulation and experiment results, and then comparing both of the results. This research used Pelton turbine type microhydro with 22 pieces of bucket. The generator that used is a PMG 200 watts type with transmission ratio of pulley 1:2. The methods used were simulation method and experimental method with varying head and diameter of a nozzle. Variable taken in this research was head variation, nozzle diameter variation, and electric power generated by Pelton turbine. Head variation used was 1,6 m, and 2,6 m, while nozzle diameter variation used was 5 mm, 7 mm, 9 mm, and 11 mm. Software used to create fluid flow and rotation simulations is SolidWorks 2013, and the instruments for testing used tachometer, flowmeter, amperemeter and digital voltmeter. The results from two methods showed that the head variable was directly proportional to power. Whereas for the nozzle variation, turbine power increases linearly as the nozzle size increases to 11 mm in diameter. Head variation 2,6 m with 11 mm nozzle diameter resulted electrical power of 11,87 watts at the volume flow rate output of 0,96 x 10^{-3} m^3/s with 269 rpm generator rotations for experiment result. Generator rotations for simulation result of the same variation is 442 rpm. The efforts to improve the electric power of a pelton turbine can be obtained from head and nozzle diameter.

INTRODUCTION

Electrical energy has a very important role for human life. In fact, in Indonesia this energy has not been fully distributed to all corners of the country. Currently, electricity in Indonesia is mostly still using fossil energy, which results in a large amount of exhaust gas emissions. Apart from having a negative impact on the environment, fossil energy is non-renewable energy, so that in the future this energy will run out. Fossil energy needs to be diverted to other renewable energy sources. The potential for renewable energy in Indonesia is enormous, and the first place is the energy potential from hydropower.

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Table 1. National Renewable Energy Potential

Renewable Energy	Power Source	Utilization	Installed Capacity
Tenaga Air	75,67 *GW*	6.851,00 *GWh*	4.200,00 *MW*
Panas Bumi	27,00 *GW*	2.593,50 *GWh*	800,00 *MW*
Bio massa	49,81 *GW*		302,40 *MW*
Tenaga Surya	4,80 $KkWh/m^2$/hari		8,00 *MW*
Tenaga Angin	9,29 *GW*		0,50 *MW*
Tenaga Nuklir	24,112 *TON* = 3 *GW*		

(Source: Rohi, 2008)

Microhydro Power Plant (PLTMH) is a small-scale power plant (less than 200 kW). PLTMH is a clean and environmentally friendly renewable energy source. PLTMH was chosen because of its simple construction, easy operation, easy maintenance and supply of spare parts, and relatively cheap operation and maintenance costs.

There are several types of turbines that are generally used in micro-hydro devices, one of which is the Pelton turbine. The characteristics of the Pelton turbine are its low water flow and the presence of a nozzle. The power and efficiency of the Pelton turbine is influenced by several factors such as the size of the water discharge, the shape of the blades, the number of blades, the number of nozzles, nozzle diameter, and head. In this study, variations in nozzle and head diameter sizes were examined to obtain the most electric power optimal. This research will also be equipped with a simulation to study how the system works and to find the best variable configuration in generating electrical power, so that the results of simulations and experiments can be compared and analyzed.

The purpose of this research is to determine the effect of variations in nozzle and head diameter and rotational speed on the electric power produced by Pelton microhydro, then how to configure the nozzle and head diameter to obtain the most optimal electric power. In addition, this study aims to compare the simulation and experimental results. PLTMH is a power plant that is generated due to water flow and height differences. Water flow and the height difference (head) are factors that must be considered in the manufacture of microhydro, because these two factors are requirements that must be met when building a PLTMH.

The Pelton turbine is a hydropower plant that is suitable for installation at high head and low water flow rates (Nasir, 2013). Pelton turbines include axial flow turbines. The water flow in the blade is carried from the reservoir to the penstock and the lower end of the penstock is connected to the nozzle. The nozzle serves to increase the speed of the jet and hit the blade so that it makes the runner rotate. The blade is fixed on the edge of the runner around the runner and the runner itself is attached to the shaft. The turbine shaft is connected to the generator shaft, where the generator works to convert the rotation produced by the turbine into useful electrical energy (Chouhan, Manish, & Mieee, 2017).

The nozzle in the Pelton turbine is important in the working process, because the nozzle has a major function in increasing turbine power. The Pelton turbine obtains hydraulic power using the impulse principle of water flow from the nozzle. Changing the number of nozzles can increase the power that will be generated by the turbine. The nozzle diameter greatly affects the dimensions of the Pelton turbine construction as a whole (especially in the blade dimensions) (Supardi and Prasetya, 2015). Microhydro gets energy from water flows that have a certain height difference. Basically, micro hydro utilizes the potential energy of water drop (head). The higher the water drop, the greater the potential energy of water which can be converted into electrical energy.

Ifham Firmansyah (2011) states that the amount of hydropower available from a water source depends on the size of the head and water discharge. The total power generated from a water turbine is the reaction between the head and the water discharge. The amount of power generated depends on the discharge and the height of the water drop. The greater the discharge and the height of the water fall, the greater the potential energy and the greater the power produced. Power has units of watts, where the amount of power can be calculated as follows:

$$P = V \times I$$

information: P = Electrical power (Watt)
V = Electrical voltage (Volt)
I = Electric current (Ampere)

Simulation is a technique to imitate the operations or processes that occur in a system with the help of computer devices and is based on certain assumptions so that the system can be studied scientifically (Law and Kelton, 1991). Simulation is the right tool to use, especially if you are required to carry out experiments in order to find the best results from the system components.

RESEARCH METHODS

The methods used in this research are simulation and experimental methods. The simulation was made using Flow Simulation and Motion Analysis available in SolidWorks 2013 software. Experiments were carried out at campus V JPTK UNS, Surakarta. Experiments were carried out on variations in nozzle diameter sizes and variations in head height with a number of 8 pairs of variables. This research does not require sampling.

Table 2. Experimental Design

	$X_{1.1}$	$X_{1.2}$	$X_{1.3}$	$X_{1.4}$
$X_{2.1}$	$Y_{1.1.1}$	$Y_{1.2.1}$	$Y_{1.3.1}$	$Y_{1.4.1}$
$X_{2.2}$	$Y_{2.1.1}$	$Y_{2.2.1}$	$Y_{2.3.1}$	$Y_{2.4.1}$

Information:
X1: Variation of nozzle diameter
X2: Head variation
Y: The electric power generated

Data collection is intended to obtain primary data. Primary data are data obtained from measurements taken directly during the testing process. Some of the data included in the primary data in this study are height (head), water flow rate, current strength, voltage, generator rotational speed and the resulting electrical power. The data analysis technique used in this research is descriptive quantitative, where what is done is analyzing the available data, processing the data, then producing conclusions.

RESULTS AND DISCUSSION

The Effect of Variation in Nozzle Diameter and Head on Electric Power (P)

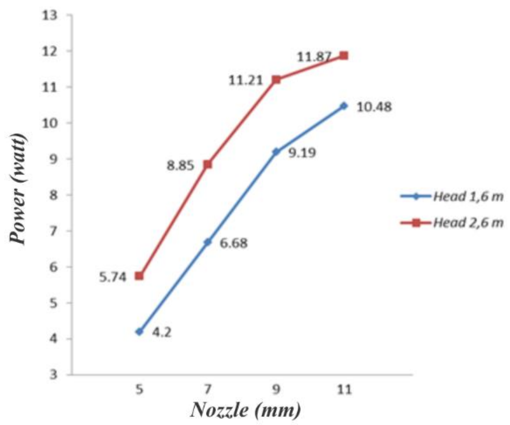

Figure 1. Electrical Power Relationship to Nozzle Diameter

The electric power at the 2.6 m head provides higher power than the 1.6 m head. The highest electric power with a value of 11.87 watts is obtained at variations in nozzle diameter of 11 mm with a head of 2.6 m. The lowest electric power with a value of 4.2 watts is obtained at a variation of the nozzle diameter of 5 mm with a head of 1.6 m.

Effect of Rotation Speed on Electric Power

This research was conducted by eliminating the electrical load. Tests that have been carried out on the rotational speed and power of the generator show that the faster the generator rotates, the greater the power produced. Each increase that occurs in the rotational speed of the generator will be followed by an increase in generator power, so it can be said that the effect between the two is directly proportional.

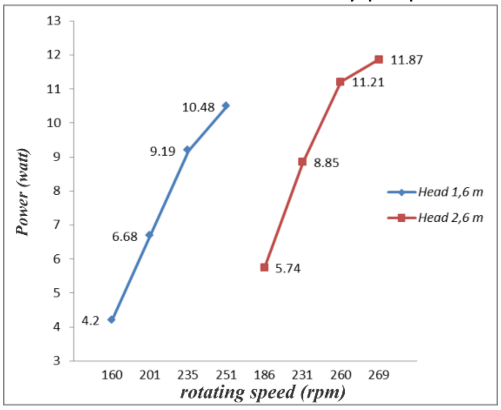

Figure 2. Relationship between Electric Power and Rotation Speed

The electric power at the 2.6 m head yields higher data than the 1.6 m head. The highest electric power with a value of 11.87 watts is obtained at a rotation speed of 269 rpm with a head of 2.6 m. The lowest electric power with a value of 4.2 watts is obtained at a rotation speed of 160 rpm with a head of 1.6 m.

Comparison between Simulation Results and Measurement Results

a. Water Discharge Comparison

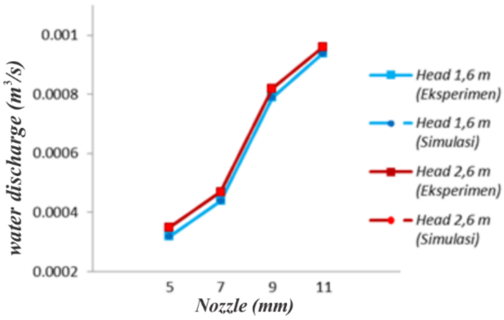

Figure 3. Comparison of Simulation Results and Water Flow Measurement Results

The water discharge in both results has increased. The simulation and measurement results did not change significantly because the data from the two results were relatively the same. Simulations and experiments show the same tendency where the increase in nozzle and head dimensions results in increased water flow.

b. Water Flow Rate Comparison

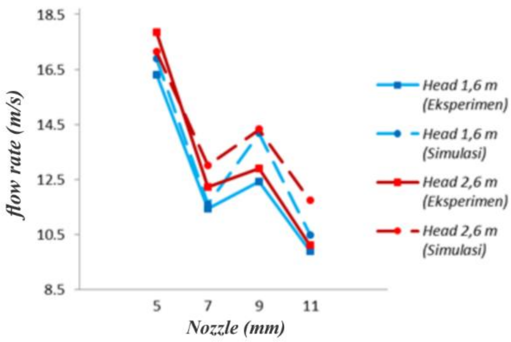

Figure 4. Comparison of Simulation Results and Calculation Results of Water Flow Velocity

The flow rate tended to decrease in both results. There are differences in the value of the two data. The simulation result graph tends to be higher than the calculation result. The difference in numbers between the two did not change significantly because the difference between the two data was not much different. Simulations and experiments show the same tendency as increasing nozzle dimensions results in a decrease in water flow velocity. The decrease in flow velocity occurred from a nozzle diameter of 5 mm to 7 mm, then at a diameter of 9 mm it increased and decreased again at a diameter of 11 mm. Globally, the magnitude of the water flow velocity between the simulation and experiment is greater than the simulation results. This is because all conditions in the simulation are assumed to be in ideal conditions.

c. Turbine Speed Comparison

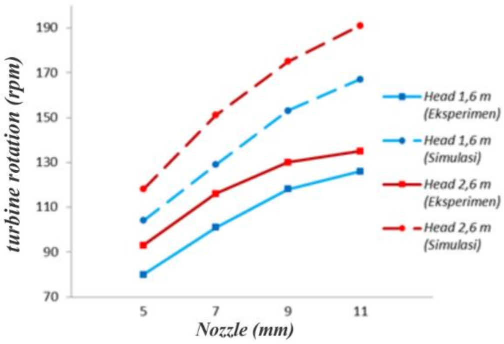

Figure 5. Comparison of Simulation Results and Turbine Speed Measurement Results

The turbine speed was both increased in both results. Either the simulation results or the measurement results are both relatively improved. There is a difference between the simulation and measurement results, but the changes seen are not so significant. Simulations and experiments show the same tendency where the increase in nozzle and head dimensions results in an increased turbine speed. However, the magnitude of the turbine rotation between simulation and experiment is greater than the simulation results. This is because all conditions in the simulation are assumed to be in ideal conditions.

d. Generator Speed Comparison

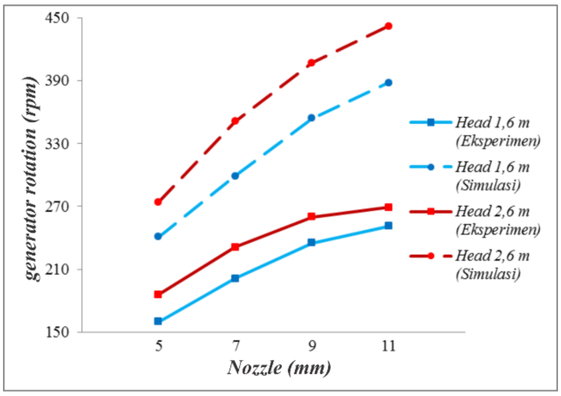

Figure 6. Comparison of Simulation Results and Generator Speed Measurement Results

The generator rotation has both increased in both results. Either the simulation results or the measurement results are both relatively improved. There is a difference between the simulation and measurement results, but the changes seen are not so significant. Simulations and experiments show the same tendency where as the nozzle and head dimensions increase, the generator speed increases. However, the magnitude of the generator rotation between simulation and experiment is greater than the simulation result. This is because all conditions in the simulation are assumed to be in ideal conditions.

CONCLUTION

Based on the results of simulations, experiments, and discussions that have been described, the following conclusions can be drawn:

1. The increase in the electric power generated by the generator is proportional to the higher the head used, namely the variation of the head of 2.6 mm. Just like the head variation, the variation in nozzle diameter has the most optimal increase in electric power at a nozzle diameter of 11 mm.

2. Electric power increases as the turbine and generator rotate faster. Each increase that occurs in the rotational speed will be followed by an increase in electric power, so that the effect between the two is directly proportional.
3. The configuration of nozzle and head diameter produces the highest electric power at a nozzle diameter of 11 mm and a head of 2.6 m, which is 11.87 watts. While the smallest electric power of 4.2 watts is generated at a head variation of 1.6 m with a nozzle variation of 5 mm.
4. The comparison between the simulation results and the experimental results shows that there are differences in data between the two. The data from the simulation results is higher than the experimental data. Although there are differences in data, the difference between the two test results does not show high significance. The simulation and experimental results show the same tendency as the nozzle dimensions increase, the results will increase. Data of water discharge, turbine rotation, and generator rotation have increased in simulations and experiments as the nozzle diameter increases, but the water flow velocity data actually decreases.

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