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Analysis of Variation in Loading of 26-Blade Crossflow Turbine in Hydroelectric Power Plant on the Torque Generated

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ABSTRACT: Hydroelectric power plants are one of the alternatives in utilizing renewable energy sources. One of the main components in a hydroelectric power generation system is a water turbine. Water turbines function to convert potential energy into mechanical energy. This study uses a crossflow type water turbine. The choice of crossflow turbines is because the turbine has a low head range so that it does not require large water pressure to rotate the turbine shaft. The purpose of this study was to determine the effect of loading on the crossflow turbine on the torque produced. The methods used in this study were literature studies and experimental studies. The turbine blades used in this study used 26 blades by providing loading starting from the lowest to the maximum load point, namely 1 to 9 kg. The water discharge flowing into the turbine is fixed at 1 m^3/minute. The results of this study indicate that the increasing load on the turbine, the average turbine rotation decreases by 14.31%. While the turbine torque increased by an average of 24.53%.

KEYWORDS: Crossflow turbine, load, rotation, torque

I. INTRODUCTION

Hydroelectric power plants are systems that use the potential energy of water on a small or large scale. The main one of the hydroelectric power plants is a water turbine. The type of water turbine used in the Crossflow turbine research where this turbine is part of the impulse turbine type used in the flow range and low. Micro hydro power plants are one of the power plants that utilize water energy as a turbine driver. The kinetic energy of water is converted or transmitted into mechanical energy in the turbine, because the water rotates the turbine blades. The mechanical energy produced is then converted into electrical energy through a generator. The use of the Crossflow Turbine type is more profitable than the use of water wheels or other types of micro hydro turbines. The use of this turbine for the same power can save the cost of making the prime mover (runner) up to 50% from the use of water wheels with the same materials. Likewise, the average efficiency or efficiency of this turbine is higher than the efficiency of the water wheel. The results of laboratory tests conducted by the West German Ossberger turbine factory concluded that the efficiency of the water wheel of the most superior type only reached 70% while the efficiency of the crossflow turbine reached 82%. The high efficiency of this crossflow turbine is due to the utilization of water energy in this turbine which is done twice, the first is the energy of water impact on the blades when the water starts to enter, and the second is the water thrust on the blades when the water is about to leave the runner [1].

The effect of the number of blades on the performance of the crossflow turbine using a variation of discharge of 0.49 l/s and 0.53 l/s and a variation of the number of blades of 15 and 30. The test results show that the torque obtained is directly proportional to the increase in discharge, rotation and number of blades so that it affects the value of the torque and power of the turbine produced. At a discharge condition of 0.49 l/s, the greatest power for 30 blades is at 89.3 rpm with a turbine power of 0.0037, the lowest power at 32 rpm, namely 0.0018 with a number of blades of 15. Meanwhile, at a condition of 0.53 l/s, the greatest power is at 98.4 rpm with a power of 0.0051 for a number of blades of 30, and the lowest power at 40.4 rpm with a power of 0.0025 for a discharge of 0.53 l/s for a number of blades of 15 [2].

The development of undershot type kinetic turbines with experimental and numerical methods has been carried out, including, in turbine testing with inlet velocities of 1 m/s, 3 m/s, and 5 m/s and variations of the number of blades of 6, 7, 8, 9, and 10. The number of blades of 8 blades with a diameter of 0.984 m is the most efficient with an inlet velocity of 1 m/s [3]. In experimental testing using two turbines simultaneously with the number of blades of 12 dimensions of the blade length of 600 mm and the blade width of 100 mm with a turbine diameter of 499 mm in a river flow with an average speed of 1 m/s, resulting in a turbine I rotation of 91 Rpm and turbine II of 78 Rpm, with a torque of 39.2 N [4]. In the study of the performance of undershot water turbines with a bowl-shaped blade model, it showed that the highest efficiency of the 4, 6 and 8 blade tests with a turbine diameter of 300 mm was obtained in a 6-blade turbine producing 20 rpm found at a discharge of 0.01228 m^3/s [5]. The maximum turbine performance at a flow direction angle of 350, the number of blades 12 diameters, 90 rpm rotation, water capacity 50 m^3/hour and with a power generated of 21,365 Watts, efficiency of 33,241%, and torque of 3,864 N.m [6]. The maximum turbine performance occurs in the turbine blade with a spoon model with a value of 0.555 Nm while the lowest torque occurs in the curved blade with a value of 0.360 Nm [7]. In the test of inclined blade water with a diameter of 1000 m, a flow rate of 0.050 m^3/s - 0.032 m^3/s at a load of 2 kg, 4 kg, 6 kg and 8 kg, the inclined blade water wheel produces a water wheel power of 17,955 Watts to 3,273 Watts at a load of 8 kg [8].

Factors that affect the characteristics of optimum turbine performance quality are the variation factor of the number of blades, the variation factor of the valve opening, and the variation of the flow inlet area. The variation factor of the number of blades of 18, 20, and 22 pieces obtained the optimum rotation result at the selected factor level A1 (18 pieces) with a rotation result of 310.2 rpm, from the variation factor of the valve opening of 50%, 75% and 100% obtained the optimum rotation result at the selected factor level B2 (75%) obtained the rotation result of 321.1 rpm, and from the variation factor of the flow inlet area of 120 mm, 125 mm, and 130 mm obtained the optimum rotation result at the selected level C1 (120 mm) obtained the rotation result of 295.7 rpm [9].

Water discharge of 0.016 m^3/s turbine with a diameter of 1500 mm with 11 blades, the highest performance (power and efficiency) is at 100 rpm, which is 20.41 Watts and the efficiency is 71.42%, the effect of water discharge on maximum torque occurs at blade 11 with a water discharge of 0.016 m^3/s at 20 rpm of 3.73 Nm, while the minimum torque occurs at blade 5 with a water discharge of 0.013 m^3/s at 100 rpm of 0.53 Nm [10].

II. RESEARCH METHODS

The materials used to make the spoons use iron pipes with a thickness of 2 mm, to make the disc plates use iron plates with a thickness of 5 mm and the axle itself uses solid iron with a diameter of 2.5 cm with a length of 35 cm.

The next stage is assembling the materials according to the predetermined design using the materials that have been prepared, then testing the assembled equipment with the first stage is turning on the inverter to turn on the pump then increasing the inverter frequency according to the standard used by rotating the inverter controller which aims to get a water discharge of 1 m^3/ minute. when the water has entered the turbine and rotated the turbine, a rotation check is carried out using a tachometer after the check is carried out, the braking load is installed by wrapping the rope around the pulley that is already on the turbine shaft after being installed, braking is carried out gradually starting from a load of 1 kg to 9 kg and each increase in braking load will be carried out data collection of rotation using a tachometer.

Research Variables

The variables of this research consist of: independent variables, dependent variables and controlled variables.

a. Independent variables are variables whose values have been determined.
   1. Water discharge: 1 m^3/minute.
   2. Number of turbine blades 26
b. The controlled variable is the load on the turbine shaft which is determined as 1, 2, 3, 4, 5, 6, 7, 8 and 9 kg.
c. The dependent variables in this study are turbine rotation and torque.

Tools and Materials

a. Turbine testing equipment installation
b. Rope brake testing equipment
c. Turbine with 24 blades
d. Measuring instruments (tachometer, flow meter and spring balance)

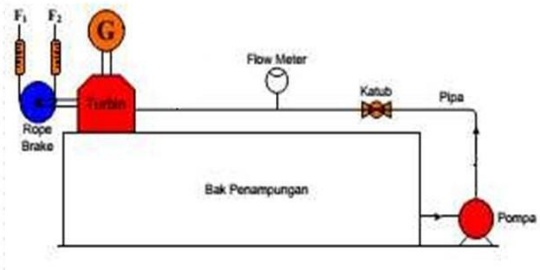

Figure 1. Turbine test equipment installation

III. RESULTS AND DISCUSSION

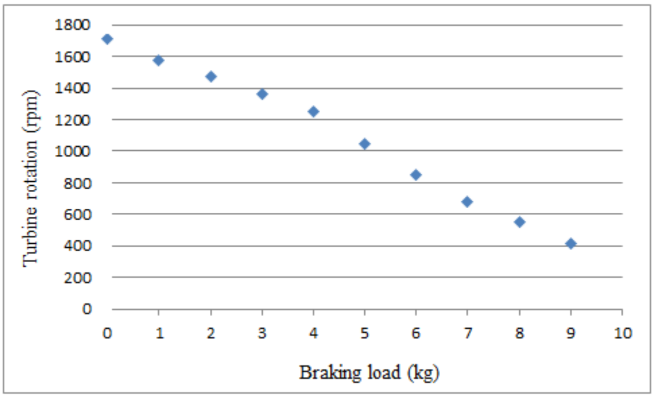

Figure 2. Relationship between braking load and turbine rotation

Figure 2 shows that the greater the load given to the turbine, the smaller the rotation produced by the turbine, and vice versa, the smaller the braking load, the higher the turbine rotation. It can be seen from the number of blades 26 without using a load of 0 kg of 1709 rpm, at a load of 1 kg of 1578 rpm and the higher the loading to the maximum load point of 9 kg the rotation of the shaft is smaller, namely 415 rpm. The increasing braking load on the turbine causes an average decrease in turbine rotation of 14.31%. This condition occurs because the greater the braking load, the greater the braking force. The greater the braking force, the greater the normal force. Likewise, if the normal force is greater, it causes the rotation of the turbine shaft to slow down or decrease.

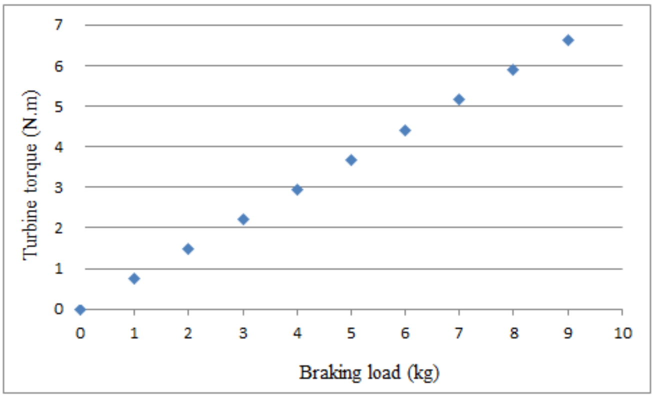

Figure 3. Relationship between braking load and turbine torque

In Figure 3, the relationship between turbine torque and loading shows that the greater the loading given, the torque value will increase. The torque value increases because the braking load given increases. Likewise, the smaller the braking load given, the lower the torque produced by the turbine [7]. This is because the magnitude of the torque is directly proportional to the braking load. The highest torque value is at a load of 9 kg, reaching 6.62 Nm and the lowest torque at a load of 1 kg with a value of 0.74 Nm. The results of the study showed that the turbine torque increased by an average of 24.53% for every 1 kg increase in braking load.

CONCLUSIONS

The turbine blades used in this study used 26 blades by providing loads starting from the lowest to the maximum load point, namely 1 to 9 kg. The air flow rate flowing into the turbine is constant, namely 1 m^3 / minute. The results of this study indicate that with increasing load on the turbine, the average turbine rotation decreased by 14.31%. Meanwhile, the turbine torque increased by an average of 24.53%.

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