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Performance of The Drag Type of Horizontal Axis Water Turbine (HAWT) as Effect of Depth to Width Ratio of Blade

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Abstract. Application of wind turbine to the water turbine is an interesting topic because of different energy momentum. A Horizontal Axis Water Turbine (HWAT) was proposed to produce energy in building the pipeline. A preliminary study using simulation and experimentally study of depth to width ratio of the blade was examined in order to determine optimum performance of the turbine using several variations of depth to width ratio of the blade with a constant head of 2 m and angle of the blocking system of 30°. Effect of the existing of different depth to width ratio of the blade for debit was reported. The optimal performance of the turbine was obtained at depth to width ratio of 0.29 that shown by highest obtained voltage of 8.62 Volt, the power output of 3.447 Watt and coefficient power of 2.73×10^{-2}.

INTRODUCTION

Pico hydro is one kind of power plants which use water for generating power below 5 kW. Developing effort for pico hydro as an alternative energy has been proposed by some researchers [1]. The drag type of vertical axis water turbine (VAWT) was applied in order to generate electric power for monitoring the quality control of water flow in the pipeline. This research also compared the solid-drag type drag turbine with a hollow-type turbine [2]. The effect of metal and ABS resin material in the manufacturing process of turbine bucket using 3D printing was also examined in a Pelton turbine bucket micro hydro [3]. Another effort was already submitted to optimize the turbine pelton using dynamics computational fluid simulation (CFD) by analyzing the effect of the designs and models, bucket depth to width ratio (*H*/*W*), and bucket exit angle to the turbine performance [4]. In this research, a drag-type horizontal axis water turbine (HAWT) was designed, applied to the pipeline, and set as close as possible to the actual state of both the discharge and the required head to examine the influence of the depth to width ratio of the blade to the power output.

RESEARCH METHOD

The design of simulated and analyzed turbine blades which have an arc angle of 70° and the number of blade 8 pieces was referred to the previous study [5-6]. After the arc and curvature angle had been decided, the depth and width of the blade were obtained. Blade depth value was divided by the width of the blade to obtain the value of depth to width ratio. Several values of the depth to width ratio of the blade, which the possibilities number was minimized using preliminary study using simulation process with ANSYS software, were applied to examine the effect of the produced power by the generator. Then the design results of the rotor were manufactured using 3D printer machine

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because there is a limitation for CNC process in handling a complex design. The preliminary study also supported the analyzing process using the visualization in the turbine housing chamber. An experimental study was conducted using test equipment which has a working principle by flowing fluid from the top tank to down as a metaphor of collected rain dropped or wastewater from the pipeline.

FIGURE 1. The sample in various depth to width ratio.

RESULTS AND DISCUSSION

Various of depth to width ratio of the blade of 0.06, 0.10, 0.14, 0.18, 0.22, 0.24, 0.27, and 0.29 as shown in Fig. 1 with the angle of the blocking system of 30º was used as main experimental part of the turbine. These blades were attached to the turbine housing which fluid flow then enter and hit the rotating blades to generate the power by attaching the AC alternator servo motors at the out of blade shaft. The water level in the test was kept in a constant value of 2 m which set by an overflow pipe mounted on a tank. In the experimental process, the obtained data were the flow rate, voltage, and electric current. Voltage and current were obtained using an AC alternator servo motors with a maximum power of 100 Watts and a maximum rotational speed of 3000 rpm. Data were collected after the flow in a steady state for a certain time to obtain data in accordance with the prescribed limits.

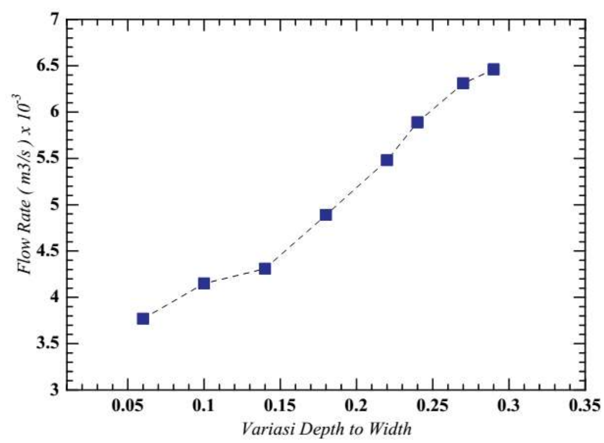
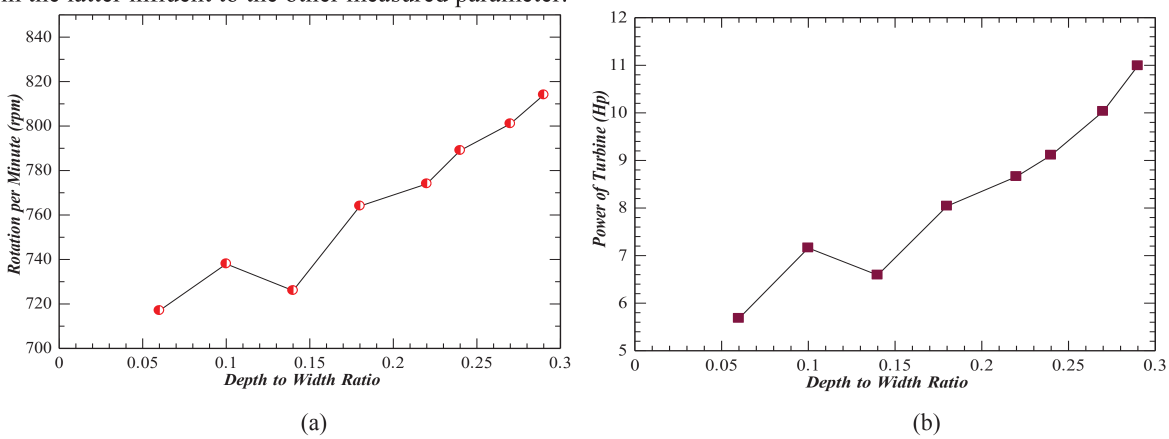


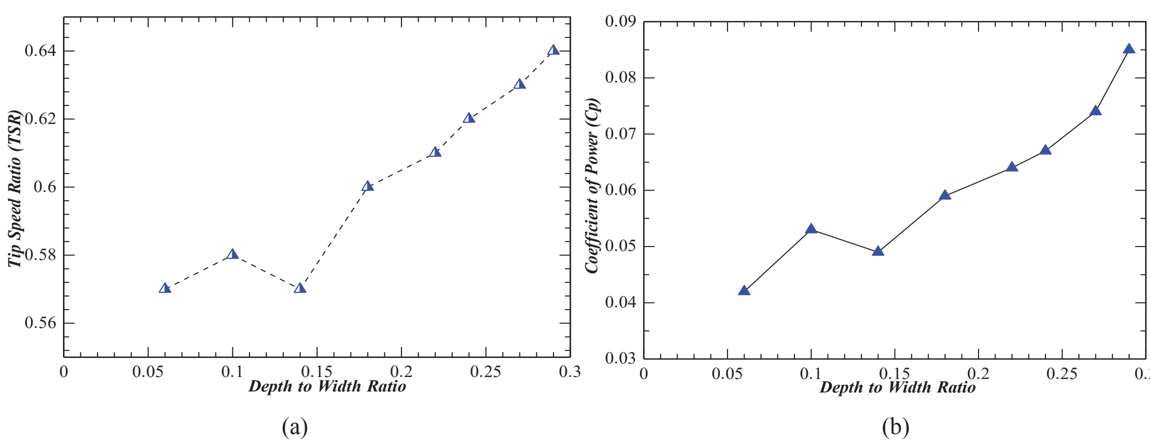
FIGURE 2. Effect of the various depth to width ratio of the turbine to the flow rates.

The flow rate of fluid greatly was affected by installed blade rotor to the system and the shape of the blade rotor which was stated by the depth to width ratio of the blade. The flow rate of fluid without installed rotor was 9.05x10^{-3} m^3/s, while for installed rotor the flow rate were 5.16 x 10^{-3} m^3/s in average value, it means the fluid suffered a loss of about 57% of flow rate. A blocking phenomenon by the blade was occurred. When the flow rate was measured in the flow after the installed turbine, oppositely the flow rates was suffered increasing phenomenon. The higher the depth to width ratio is given, the greater the flow of fluid as shown in Fig. 2. The highest debit of 6.46 m^3/s was obtained at the depth to width ratio of 0.29 because in the highest depth to width ration the shape of the blade depth has the greatest volume. In depth to width ratio of 0.15, there is a slight decrease of the flow rate that shows an indication of flow leakage. In depth to width ratio of 0.15, because of the angle of the blade was big, the endplate of the blade start to escape from the shaft body, see Fig. 1. This leakage compensates to the decreasing flowrates which in the latter influent to the other measured parameter.



FIGURES 3. Effect of the depth to width ratio to (a) rotation speed and (b) Tip Speed Ratio (TSR)

One of the important parameters used to describe the performance of the turbine is the Tip Speed Ratio (*TSR*) that shows the ratio of the tangential speed of the blade with the actual speed of the fluid. TSR is a equations function of the angular velocity/angular velocity (ω), diameter (D), and the incoming fluid velocity (U). Where the angular velocity/angular velocity (ω) is a vector quantity that states the frequency of an object and the angle of the axis of rotation. The fluid flow velocity (U) is obtained by using the function of incoming fluid flow (Q) and the cross-sectional area (A) of 0.001305 m^2. Based on the experiment, the velocity of the fluid flow increased as shown by other research [1]. Figure 4(a) shows that the value of Tip Speed Ratio (TSR) on the variation of depth to width increase. This is because the velocity of fluid flow that works on each of the different variations of depth to width. Speed fluid used to divide the angular velocity explained that the Tip Speed Ratio (TSR) which is optimal based on the value of the fluid velocity variation of depth to width is 0.29, with the value of Tip Speed Ratio (TSR) 0.61. Rotor performance can be obtained by plotting the data voltage, power and power coefficient of variation obtained depth to width of the blade. Figure 4.1(b) is the electrical power produced, where, P_o is the output power (Watts), V is the voltage (Volt), and I is the electric current (A). The most optimal electrical power is a variation of depth to width of 0.29 with a value of 3.447 W.



FIGURES 4. Effect of the depth to width ratio to (a) Tip Speed Ratio (TSR) and (b) coefficient power.

At depth to width ratio of 0.06 the voltage was obtained 5.20 V and then the voltage became to be 8.62 V at depth to width ratio of 0.29. The maximum output power was obtained was 3.447 W at the value of depth to width ratio of 0.29, and the greatest power coefficient was 2.73×10^{-2} at depth to width ratio of 0.29. It can we associate with parametric simulation studies Pelton turbine which explains that the effect of depth to width design has an efficiency of not more than 1% [4]. At the depth to width ratio of 0.29 the highest obtained velocity, pressure, and torque were 2.821x10 m/s, 4.230×10^{5} Pa and 2.704 Nm respectively.

CONCLUSIONS

From research conducted using the Horizontal Axis Water Turbine (HAWT) the conclusion are:

1. The blade shape affects fluid flow velocity
2. The greater the flow rate, the greater the generated power.
3. Depth to width ratio of 0.29 has the best performance.

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