THE UTILIZATION OF HORIZONTAL PIPELINE FOR A STATIC BULB TURBINE AND THE DETERMINATION OF OPTIMUM BLADE NUMBER USING FLOW SIMULATION

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Abstract

The potential for small-scale hydropower plants in Indonesia has the opportunity to be developed. One of these potentials is the water channel that passes through the piping system. The dynamic bulb often used at small-scale hydropower plants propeller turbines in horizontal flow water piping systems, while static bulb use has not been studied further. Moreover, one of the geometries that affect the performance of propeller turbines is the number of blades. This study aims to determine the characteristics of propeller turbines that give a static bulb, the number of blades was variated between 3 to 7. SolidWorks 2016 flow simulation software is used as numerical simulation method. The results of this study indicate that the use of bulb static produced higher torque than dynamic bulbs while the optimal torque value is achieved in the number of blades 6.

Keywords: bulb turbine, propeller, number of blade, flow simulation

INTRODUCTION

Indonesia has abundant natural resources, one of which is water with an environmentally friendly and sustainable energy source. The potential of water energy sources in Indonesia reaches 75000 MW, but only around 9% are used as large-scale and small-scale plants [1]. Pico scale power plants (maximum energy potential of 5 kW) in water energy sources can be obtained in water channels or water systems including small rivers, irrigation channels, pumping stations, piping systems, etc. [2].

In general, there are two categories of water turbines, impulse turbine and reaction turbines. Impulse turbines are commonly used in medium to high head with a small discharge, while the reaction turbines used in low head with high discharge. Propeller turbines are often used in horizontal reactions. The advantages of propeller turbines are practical, high efficiency, and relatively small production costs [3].

The type of propeller turbine consists of four forms, namely bulb turbine, starflo, tube turbine, and Kaplan [3]. Power plants in piping systems of full capacity turbine type, turbine bulbs are used more often because their performance is better than other forms [4]. The bulb body on the bulb turbine is located before the guide propeller and runner which aims to increase speed and direct fluid to the runner [5].

In general, the body bulb used in the propeller turbine has 2 type, namely a dynamic bulb that is one part with a turbine (Figure 1), and a static bulb complete with its turbine (Figure 2).

To analyze the tangential velocity distribution in the static bulb scheme, it is divided into five regions as shown in Figure 2. While Figure 3 shows the tangential velocity graph of each region, the inlet value is 0, then lucratively rises after passing through
the bulb, and when entering the guide vane (b) this increase is due to the narrowing of the waterway. The next guide vane changes the direction of flow before going to the runner so that the tangential speed rises (c). Because the narrowing of the inlet runner velocity area increases drastically (d). The velocity value decreases rapidly after the flow of water crosses the runner; this decrease is due to tangential velocity kinetic energy converted by runners to mechanical power [7].

The use of propeller turbines in horizontal or tubular pipelines shows high performance. Some previous experimental studies on a laboratory scale using dynamic bulb showed efficiencies above 60% [6] [8] [9] [10]. While to date studies of the use of new bulb statistics have been limited to tidal power plants [7] [4]. In the laboratory scale with a discharge that is comparable to the tides shows higher turbine performance than the dynamic bulb with efficiency reaching 91.7% on the blade angle 25° [4].

Figure 3. Tangential velocity on the bulb statistics based on the area [7]

The water turbine geometry parameters will provide characteristic information on its performance so that optimal design results will be obtained with the conditions facilitated [11]. One of the geometries that affect the characteristics of the propeller turbine is the number of blades that affect the gap between blades. In the same water flow the gap between the blades causes the air flow and pressure distribution on the surface of the blade to be different [12]. Axial force is rising along with increasing numbers of blades, but the decreasing number of blades the smaller the flow of smaller turbines that increase tangential speed decreases [13].

Based on previous research, the performance of static bulb was higher than dynamic bulbs. In addition, the number of blades also affects the performance of the turbine propellers. the topic used in this study is the bulb statistics on propeller
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turbines which are applied in the pipeline with the number of blades as the variation. The purpose of this study is to provide information about the simulation of the results between dynamic balls and bulb statistics static??, as well as the selection of the optimal number of blades in the design of tubular bulb turbines.

METHODOLOGY

Research design

The turbine blade design used in this study refers to research [9] [10], with a blade slope of 25°, in the inlet and outlet hub angle of 41 and 17 degrees respectively, and tip angle 26 and 17 degrees inlet and outlet. Turbine diameter refers to research [6] [8], that is 84.5 mm. The turbine blade design is shown in Figure 4. While this pipeline channel scheme refers to the study [4], with a ratio between the bulb and the main drain pipe 0.6 shown in Figure 5. Variables for the number of blades used in this study are 3 to 7.

Simulation analysis used in this study uses the finite element method with three-dimensional flow simulation Solidworks 2016 with several settings for meshing and determining boundary conditions.

Meshing and Boundary Condition

Meshing settings are used to divide parts of structures or components into nodes and elements. The meshing settings used in this study are automatic at level 5.

Meanwhile, the simulation flow in the input channel uses a flow inlet volume parameter of 0.0208 m³ / s; the output channel uses a parameter environmental pressure or 101325 Pa. While the objectives set in this simulation use the surface area of each blade, with the parameters used by SG Torque (X). In general, the upper limit in this simulation is in Figure 6.

RESULTS AND DISCUSSION

The results of the running simulation obtained the torque value as shown in Figure 7. The optimum torque value in this study was obtained on a static bulb with the number of blades 6 and decrease in the number of blades 7. The lowest torque value was obtained on the dynamic bulb with the number of blades 3. Figure 7 shows based on the polynomial trendline torque generated on the turbine using a static bulb higher than the dynamic bulb.
Effect Add Static Bulb

In the static bulb, water passes through some constriction so that the velocity of the water flow increases, this is shown in Figure 8 which illustrates the contour of the speed of the static bulb flow. The figure shows that there are some drastic increases in velocity before entering the runner which show different color velocity contours up to the highest speed of the area before the runner indicated by the dark red contour [7]. In contrast to the dynamic bulb shown in Figure 9, the increase in water flow velocity only occurs in the narrowing of the pipe as indicated by the orange velocity contour before the runner.

Based on Figure 8 and Figure 9 shows the water flow velocity before entering the runner on the static bulb higher than the dynamic bulb. In general at higher speeds the flow of water has higher kinetic energy; this is due to the value of the kinetic water energy comparable to the velocity value of the water flow. So that at the speed of the water flow higher when pounding the blade will produce greater torque.

Effect Number Of Blade

Figures 10, 11, and 12 show the pressure contours of the number 3, 6, and 7 blades. The pressure contour of each image around the bulb between the static bulb and the dynamic bulb is equally. This shows that the narrowing of the area does not cause blockage of flow in the use of static bulbs.
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Figure 10. 3 blade number contour

Figure 11. 6 blade number contour

The color degradation pressure contour is higher until the number of blades 6 and no blockage occurs as shown in Figure 11, while the color degradation in the turbine as shown in Figure 14 shows that the flow pressure pulverizing the blade is greater resulting in a greater axial force than the number of blades less [13].

Figure 12. 7 blade number contour

Flow blockage occurs in the number of blades 7; Figure 12 shows high pressure occurring in the area before the runner with a dark red pressure contour. While the color degradation of the turbine Figure 15 shows a pressure contour that is greater than blade 6, but the gap between the blades that are getting closer causes narrowing of the space between the blades [12] so that the waste disposal of the water flowing through the turbine decreases [13].

Figure 13. Turbine pressure contours in number of blades 3
CONCLUSIONS

From numerical simulations carried out by this research propeller turbines using static bulbs show higher torque values than using dynamic bulbs. Based on the pressure contour, the color gradation on the propeller turbine that uses the bulb statistics increases several times the speed increase.

The torque value will increase as the number of blades increases until the optimum number of blades 6, then starts to decrease when the number of blades 7. Based on the pressure contour, the color gradation in the number of blades 3 and 6 does not block the discharge capacity, while in the number of blades 7 there is a blockage of the discharge capacity, this is indicated by the pressure contour before the high runner with dark red gradations.

DAFTAR PUSTAKA


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