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The Improvement of Electrical Power Generated By Pump as Turbine Using Guide Vane

D.L Zariatin[1*], Taruna[1,2], Danies Seda[1], Ismail[1], Agri Suwandi[1]
[1]Mechanical Engineering Department, Universitas Pancasila, Jakarta, Indonesia
[2]PT. Integrated Healthcare Indonesia (J&J Indonesia), Indonesia

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ABSTRACT

One of the problems faced by micro hydropower plant, including Pump as Turbine is low efficiency. Pump as Turbine (PAT) is one of micro-hydro power plant that uses a centrifugal pump as the turbine and modifies the pump motor to become a generator. Researches tried to improve the PAT efficiency by modifying the impeller and pump housing in order to optimize the flow that rotates the generator shaft. However, there is still another possibility of modifying and improving the water flow by using a regulating or guide vane. This research aims to improve PAT efficiency by conditioning the water inlet using a guide vane in a vertical direction. The regulating vane with a diameter of 56 mm has four vanes made of stainless steel. The vane is adjustable so that the vane opening can be regulated. In this research, the vane opening was setting at 0°, 30°, 45°, and 65°. The experimental test was performed at a PAT power plant's laboratory scale with a head of 3.7 m above the ground. The regulating vane was placed on 260 and 400 mm above the PAT. It showed that the power increased 7% when the guide vane placed 400 mm above the pump shaft with a 45° of vane opening.

INTRODUCTION

Hydropower is the oldest power generation that can provide clean and sustains energy. Technology is matured and already implemented in many countries. In a big hydropower plant, 70-75% of the investment goes to civil works and landscapes [1]. On the other hand, for a rural and a remote area, a micro or even Pico size power plant is more suitable. However, one of the difficulties of building a micro or a pico-hydropower plant is to find a turbine in a small capacity. Pump as a turbine (PAT) as one hydropower uses a centrifugal pump to generate electric power. In PAT, the water flows in the opposite direction. The impeller act as the turbine, meanwhile the motor is modified into a generator. One of PAT problems is lower efficiency compare to conventional turbines [2]. However, the advantage of PAT [3] is low-cost, availability, a wide range of operation, simple design, ease of installation, spare parts are readily available, and long life term.

Up till now, impeller modification to improve the PAT efficiency is prevalent [4][5][6][7][8]. However, there are other possibilities to improve PAT efficiency in terms of flow modification, such as the usage of regulating vane. Ferro et al. [9] proposed a quasi-three-dimensional method to designed an inlet guide vane system for a mini hydraulic bulb-turbine. The guide vane consists of six curvature shape blade vanes that were designed by considering the flow-rate, available head, rotor angular speed of the generator, upstream and downstream velocity diagram of blade rows, and blade geometry. Computational analysis using Fluent was compared to the experimental result performed using air as the working fluid. The validation showed that the proposed method was sufficient to use.

*Corresponding author.
E-mail address: dedeliazariatin@univpancasila.ac.id
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The performance of a pump in the turbine mode resembles the performance in pump mode, i.e., a high-efficiency pump works better in the turbine mode. In centrifugal pumps, mainly three types of casings are used, e.g.volute casing, vortex casing, and diffuser casing with guide vanes [8]. Yasi and Hashemloo [10] used a guide vane mechanism in an axial micro-hydro of Kaplan type to improve efficiency. Several tests were performed to measure the performance for three conditions, which was without installing guide vane, installing guide vane with 0%, and 10% of guide blades opening. It is found that the highest efficiency was achieved when the guide vane was 0% opened — the objective of this research to investigate the improvement of the PAT power plant when using a guide vane.

EXPERIMENTAL METHOD

The guide vane design was adopted from air regulating vane or air dumper that was available in the market [11] and customized according to the test facility in the laboratory [12]. Figure 1 shows the guide vane and its components. It has four knock-down components, which are (a) vane; (b) upper; (c) middle; and (d) bottom part. The vane, upper and the bottom part was made of stainless steel. Meanwhile, the middle part was made of polyoxymethylene. The guide vane has a total height of 167 mm, outer and inner diameter of 100 and 60 mm, respectively. The vane has 4 (four) blades that can be adjusted by rotating the middle part and tightens the four screws, as shown in Figure 1 (e). The system works efficiently and simply. To regulate vane opening can be performed by loosening four fasteners' bolts and then rotating the top of the clock. Marking the angle of opening has been made by positioning the line at the desired angle. In this research, the vane opening was 30°, 45°, and 65°.

The test was performed in a laboratory-scale test facility, as shown in Figure 2. The head of the water level in the tank to the PAT shaft is 2.5 m. The flow-rate was controlled by an adjusting valve placed under the tank. A Sea DNS sensor was used to measure the flow-rate. A digital tachometer with an accuracy of 0.05%+1 and a sampling ratio of 0.8 over 60 rpm was used to measure the flywheel's rotational speed. Two digital multi-testers (Fluke II with accuracy ±0.4%+1) were used to measure the voltage and current. The power-law equation calculated the electric power, which is multiplying the measured voltage and current, P = I.V (Watt).

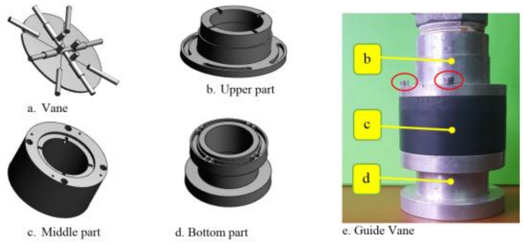

Fig. 1. The Guide Vane

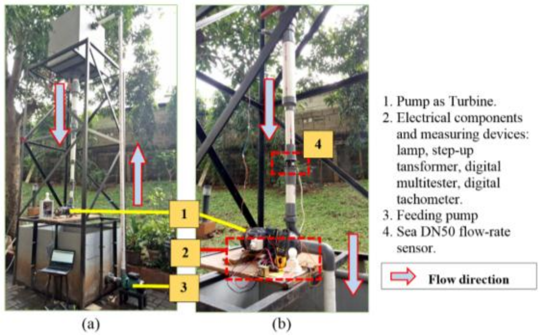

Fig. 2. Laboratory Scale Test Facility [13]

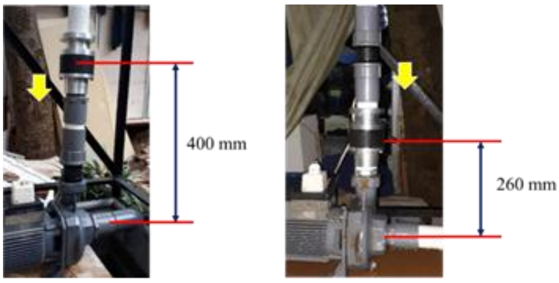

Fig. 3. Regulating Vane Position

Three-level of vane opening, which is 30º, 45º, and 60º with two different vanes of regulating vane, were tested in this experiment. The guide vane position was 400 mm and 260 mm from the PAT shaft, as shown in Figure 3. The vane opening degree was adjusted by rotating the middle part of the guide vane. There is a scaling sign on the middle part for easier adjusting.

RESULTS AND DISCUSSION

Figures 4, 5, and 6 show the experimental result for each position (400 mm and 260 mm) and guide vane opening (30º, 45º, and 65º) in comparison without guide vane. The graphic shows that the power increased as the flow-rate increased. When not using a guide vane, the power plant generated 49.65 Watts with a measured shaft generator rotational speed of 1119 rpm. Figure 4 shows that the use of guide vane with a 30º vane opening was not sufficient to increase the power generation. Placing guide vane at 260 mm and 400 mm above the shaft only generated 41.09 Watt and 42.83 Watt. It is less than the power generated without using guide vane.

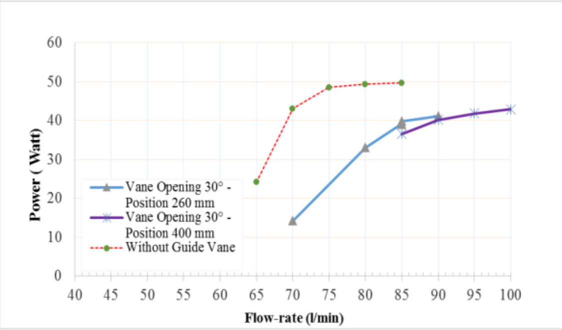

Fig. 4. Comparison of the power generated on 30º Vane Opening

Figure 5 shows that placing the guide vane 400 mm with a 45° vane opening generated 53.85 Watt. Meanwhile, the power generated when the guide vane placed 260 mm above the shaft was 42.81 Watt. Compared with the power generated when not using guide vane, placing 400 mm above the shaft with 45º vane opening increases the power up to 7%. However, there is no improvement when the guide vane is placed 260 mm above the pump shaft.

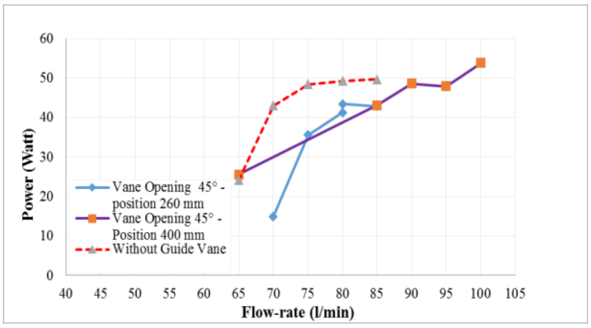

Fig. 5. Comparison of the power generated on 45º Vane Opening

The power generated by the guide vane with 60° vane opening that place 260 mm and 400 mm is 45.11 and 42.33 Watt, respectively. Figure 6 plot the data for the experiment. It shows that there is no upgrading of power when utilizing 60° for the vane opening.

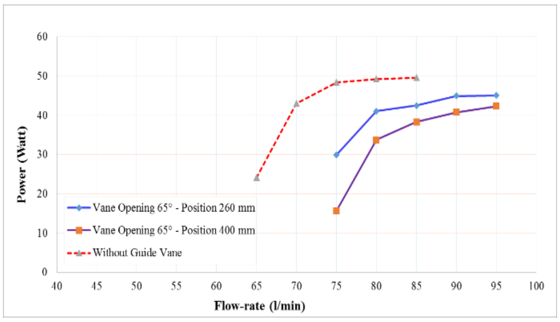

Fig. 6. Comparison of the power generated on 65º Vane Opening

CONCLUSION

In this research, a vertical guide vane was successfully designed and manufactured. The experimental test was performed for two positions of guide vane, 260 mm and 400 mm above the pump shaft, with three variations of vane opening: 30°, 45°, and 65°. The power was calculated by multiplying the electric voltage and current measured by a digital multi-tester. The experimental result shows that placing a guide vane 400 mm above the pump shaft increased the power up to 7%.

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