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Experimental Study on the Effects of Turbine Blades Types on the Performance of Centrifugal Pump as Pico-Hydropower Generation

Asral[1,*], Ridwan Abdurrahman[1], Lely Deswita[2]

[1] Department of Mechanical Engineering, Engineering Faculty, Universitas Riau, Kampus Bina Widya Jl. HR. Soebrantas Km 12,5 Simpang Baru Panam, 28293 Pekanbaru, Riau, Indonesia

[2] Department of Mathematics, Faculty of Mathematics and Science, Universitas Riau, Kampus Bina Widya Jl. HR. Soebrantas Km 12,5 Simpang Baru Panam, 28293 Pekanbaru, Riau, Indonesia

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ABSTRACT

Turbines are rotary mechanical devices used to extract energy from rivers with waterfall and convert them into electricity for rural areas. However, many small turbines installed in rural areas are expensive and dependent on the types of blades to provide the required energy. Therefore, this study aims to determine the effects of backward, inclined, and forward blades of turbines on the centrifugal pump's performance as pico-hydro power. This study was carried out in Riau Province due to the low flow of water, with varying turbine blades for small-scale hydropower generation. Rust-resistant and lightweight materials were selected for the manufacture of the turbine and to keep it from damaging. The turbine was tested in a laboratory to determine the characteristics and maximum power output from rivers and waterfall. The result showed that the turbine produces a maximum electrical power of approximately 1000 Watts using the backward blades due to its ability to support and save water resources.

1. Introduction

This study aims to determine the utilization of water resources for hydroelectric power generation in rural areas. The research was carried out based on several previous studies on electricity generation using turbines, such as Wu and Chen [1], Adhau *et al.,* [2], and Tarjuelo *et al.,* [3]. Therefore, the effort to make the most of the energy coming from the water channel system has led to the innovation and development of hydro matrix power wheels, which can produce most electric energy, known as the turbine [4]. Previously, nine small-sized water wheels arranged like a matrix situated on a small river were developed, with no report on the effect of the method on each waterwheel's performance. Furthermore, the development of a waterwheel has been traditionally carried out and used to fulfill the energy needs in the agricultural area [5]. In the application of small-scale turbines, the ratio of blade height to inlet water needs to be considered. In a study it was shown that the ratio of blade height to incoming water h/l = 1 produces greater power and efficiency than

* *Corresponding author.*
E-mail address: asral@lecturer.unri.ac.id

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others [6]. In a region wherein the water resources are available in abundance, turbines are highly recommended as a solution to energy deficiency in rural areas. Conversely, Indonesia's potential for hydropower is approximately 75.5 GW [7].

A significant amount of electricity capable of being utilized in rural areas can be generated from rivers. Therefore, the regulation and optimizing of water resources for consumption, irrigation, and hydroelectric power plant need to be considered in accordance with the study carried out by Wu and Chen [1]. Similarly, this study is essential to improve the energy produced by a water power plant in electricity generation [8].

Pico hydro water turbine is an alternative technology for electricity generation from a hydroelectric plant small size. It is suitable for use in rural areas due to conventional construction costs and technology. A research carried out by Keawsuntia [9] stated that a water power plant designed with a pico cross-flow turbine can store energies in batteries of 12V. Further examination reported that the pico cross-flow turbine with a wheel diameter of 0.8 m and 20 blades has the shape of a semi-circle diameter of 0.1 m, with a blade length of 0.8 m. The results showed that the system generates a maximum electrical power of 145.42 watts or 3:49 kW-hours per day, which is enough for 6 families in rural areas, with a return rate of $ 0023 per kW-hour. A computational study by varying the preload from 0 N.m to 60 N.m, head 1 m and flow rate of 10.5 kg/s shows that cross flow turbine performance is greatly affected by loading. The highest performance is about 60 % achieved at a loading close to 45 N.m [10].

Many studies have been conducted in order to determine the proper utilization of water energy resources. For instance, a study carried out by Ridzuan *et al.,* [11] illustrated a description of the initial testing performed on the prototype pico hydro generator system in order to investigate the performance [11]. Furthermore, the kinetic energy contained in the flow of water in domestic pipes is known to have the potential to generate electricity for energy storage purposes while performing daily activities such as laundry, cooking, and bathing. The water pressure and flow in the pipe from the main tank is utilized by small-scale hydro turbines to rotate and drive a generator to generate electricity. The results indicate that the readings are significantly convincing in terms of electrical voltage recorded due to its feasible calculation ability for electrification to store energy and for future improvement.

Zhang *et al.,* [12] carried out a study by designing appliances using small hydroelectric power plants based on an analysis of existing hydropower's technological characteristics and shortcomings. The device can be used as a supplement to conventional power plants, and in places where the state does not have a dam, rather it has several water resources. The working principles of the new devices are introduced, and the analysis of motion and force are determined. Furthermore, a schematic design showed the feasibility through theoretical analysis, while tests on the model prove that the new hydropower has high efficiency.

In order to properly utilize the renewable resources for the provision of free energy the development of pico-hydro turbine into a proper object to be investigated. Therefore, this study focused on determining centrifugal pumps' performance, such as turbines, to produce electricity and determine the power generated in waterfalls.

2. Methodology

This study was carried out in a laboratory, with a small turbine's centrifugal pumps used to change the function and various types of blades, such as backward, inclined, and forward-curved. Furthermore, this study was carried out by varying the type of blades mounted in the impeller (rotor), as shown in Figure 1 and Figure 2. The turbine components used in this study went through a design

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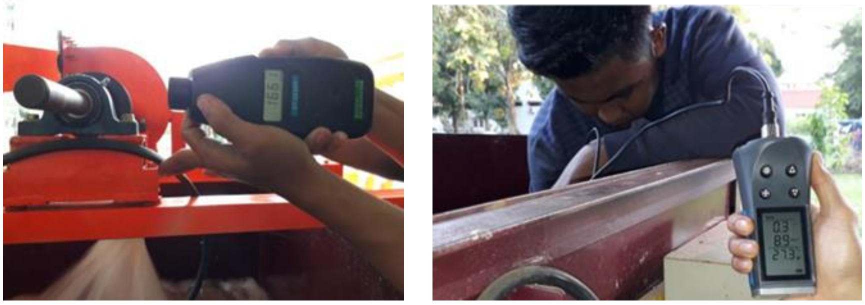
process based on field survey data. like volute and impeller of the turbine, the flow of water entering the turbine is regulated according to conditions in the field.

The forward, inclined, and backward curved blades of the turbine, were sequentially determined in carrying out the research. For every blade test, the impeller was loosened from the volute, with the output and input of water flow circulated from two water tanks, with the turbine stationed on top. Furthermore, the flow was controlled with a gate valve positioned in the tank with an electric generator mounted on top of the reservoir, also connected to power in the turbine. In all variations, the parameters measured were rotation, flow rate, and electrical voltage output (V). Measurements were made for a certain time to determine the effect of turbine performance.

Fig. 1. The arrangement of the turbine apparatus



(a) (b)

Fig. 2. Methods for rotations and flow mensuration. (a) Rotation (b) Flow rate

3. Results

The varying valve opening with a flow regulator used to determine the effect of flow velocity is shown in Figure 3. The turbine is tested without loading and by not connecting it to the generator in order to absorb the energy flow absorbed only by the turbine. The results showed that backward blades require a higher flow of energy compared to others. To achieve the best performance, a pump with a backward curve blade should operate at a fairly high flow rate. this is similar to the results of a study conducted by Vásquez *et al.,* [13]. This implies that the turbine needs a lot of water in its operation to ensure the valve opening generally increases the amount of flow.

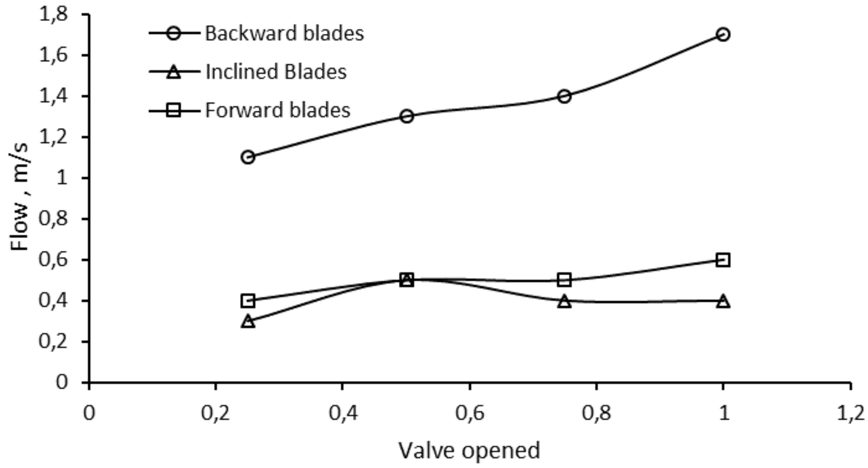


Fig. 3. Characteristics of flow for a different type of blades

Figure 4 shows the change in flow rate when the electrical load is increased with a higher source of water consumption with the application of the forward blade. It anticipates the excess supply of turbines with a straight type blade to produce limited electricity during the dry season. However, turbines with backward blade types provide optimal solutions to this problem.

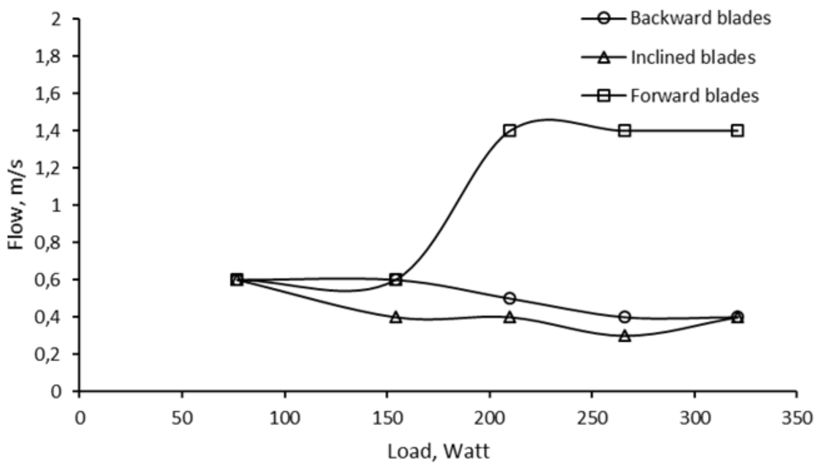


Fig. 4. Characteristic of loading on water needs with different types of blades

Figure 5 shows that an increase in electricity load leads to a decrease in the turbine's electric current. The decrease is more significant compared to the effect caused by the amount of flow rate. This result implies that some of the energy of water that has not been appropriately converted is due to losses. In terms of comparison, the backward blade performed better than others.

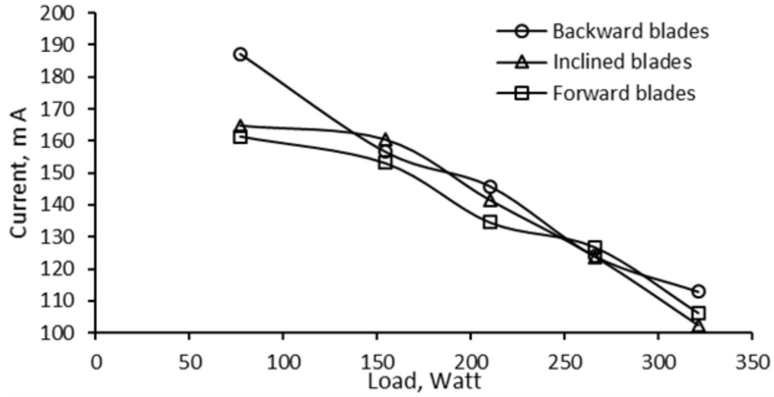


Fig. 5. Characteristics increasing loads on the flow rate

Figure 6 shows that an increase in electricity load leads to a decrease in the generator's shaft rotation. Therefore, to provide high efficiency, the shaft rotation turbines need to be maintained in line with the increase in electrical load. Furthermore, the decrease in the rotation is due to the reduction in the blade, followed by a decrease in flow rate. These results indicate that the turbine decreases its power capacity when operating in a state of resourceful deficit. Furthermore, the change in blades shape does not show important problem-solving results, therefore, modification is the need for a more resilient energy reservation. These results show the similarity of output power characteristics with a study conducted by Bachtiar *et al.,* [14].

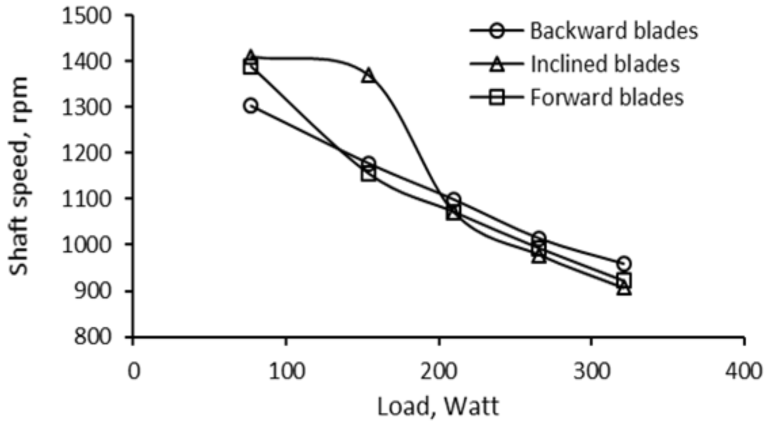


Fig. 6. The characteristics of rotation with a type of blade and electric load varies

Figure 7 shows that an increase in electrical load leads to a decrease in voltage. Changes in the type of blade used in the turbine provide the same effect, leading to a continuous decrease in electrical voltage. These results indicate the absorption of energy contained by water in the form of reduced rotation, which triggers a magnetic field in the generator. Therefore, to increase the voltage again, the flow needs to be raised to push the turbine blade with the appropriate force. The output energy of the turbine with the backward blade type seems to produce slightly better performance than the others. These results illustrate the suitability of the data presented in a study regarding the effect of backward blade size conducted by Himawanto *et al.,* [15].

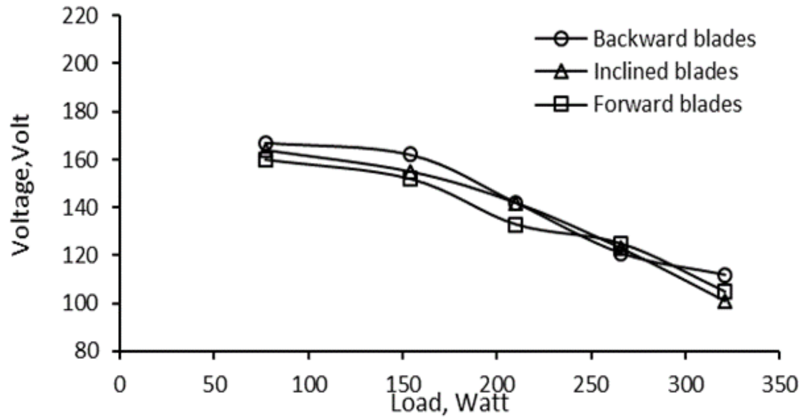


Fig. 7. Characteristic of voltages with the type of blades and electrical loads

4. Conclusions

This study reveals the performance of various types of turbine blades for low head installations. Therefore, the following conclusions were made

i. The straight blade (inclined) is appropriate for the pico-hydropower.
ii. The backward blade is essential for the proper generation of electrical power in turbines.
iii. The type of blade installed in the turbine can save the water resources in Riau province during the dry season.

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