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VERTICAL AND HORIZONTAL NOZZLE EFFECTIVENESS IN CROSS FLOW TURBINES

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ABSTRACT

A Cross flow turbine is a most beneficial prime mover, compared to waterwheels and other micro hydro turbines, to convert water potential energy into mechanical energy as an electric generator prime mover. A cross flow turbine has a nozzle that functions to spray the water, converts the water potential energy into kinetic energy, directs the water jet to hit the turbine blade runner which causes the cross flow turbine shaft to spin. This study aims to determine the effectiveness of a vertical and a horizontal nozzle on a cross flow turbine performance.

Keywords: Effectiveness, Nozzle, Cross Flow Turbine
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1. INTRODUCTION

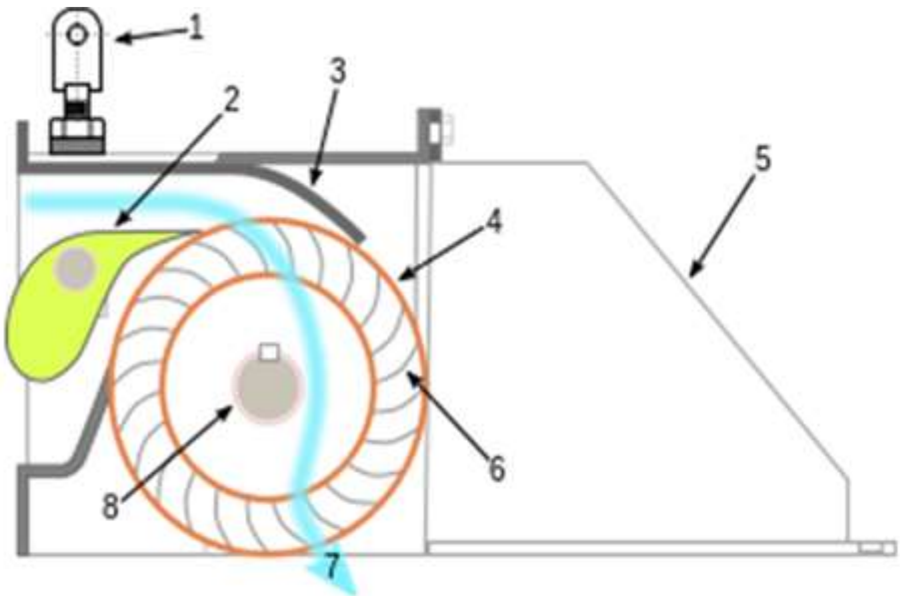
Geographically, many areas have a water energy potential, either smaller scale or medium and large scale, that can be used for sustainable development in the future. A lot of people have promoted the water energy potential importance, investigating the benefit either technically or economically and environmentally [1]. In general, the development acceleration and the environmentally friendly and renewable energy utilization can be realized as a sustainable development support [2]. In remote areas there is a lot of qualified water energy potential to be developed as a clean energy source. It can substantially contribute to reduce the rural poverty number. Along with the rapid development of human civilization, causing a lot of irrigation dams, flood prevention constructions, water banks, multipurpose reservoirs, which have not been used as reservoirs to generate electricity [3]. At the international level, water energy is seen and understood as a natural source very important, clean and sustainable as an energy source to generate electricity. The population growth, technological and industrial developments have resulted in an increase in energy consumption, so that efforts must be made to increase the energy supply. The economic building and development to achieve the reasonable community life standard will increase the energy demand in the future. Electrical energy is the most widely used in supporting human life, wherever human lives, electricity has become a primary necessity for everyone either in urban or in rural areas the need for electricity continues to increase [4].

This condition can change the people's mindset, how to implement and use a new and renewable energy sources such as water energy as well as possible. Water energy is a renewable energy resource that can be obtained directly from nature. The water energy resource potential is available, very large, in rural areas, to be used as a source of electricity because the water potential is sufficient, appropriate, cheap, environmentally friendly and sustainable. The main component of the power generation system is not too complicated because it only consists of a water turbine to be able to convert water energy converted into mechanical energy on the turbine shaft. Head and water flow capacities are very important, to be taken into account and considered, in utilizing the water flow energy potential in a micro scale power generation system [5]. The small-scale water energy generation cost is very appropriate and most effective for supplying electricity to remote rural areas that is far from large-scale plants and not accessible to electricity.

Many micro hydro power plants use cross flow turbines for their prime mover. The cross flow turbine is very suitable and feasible in hilly areas with a small water flow rate, low heads and could be adapted to the available location characteristics [6]. The cross flow turbine performance produced is very determined and influenced by the turbine structure, water flow rate, turbine runner blade, nozzle position and nozzle shape, the blade angle and blade number on the turbine runner. The turbine runner is functioning to absorb the kinetic energy from the nozzle which pushes and moves the blade on the runner [7]. This energy is then converted to a mechanical energy to rotate the turbine runner. In cross flow turbines, kinetic energy is the water pressure energy [8]. It can be converted into kinetic energy in the form of water jets from the nozzle. The water jet flow is entering the blade runner and converted the kinetic energy into a mechanical energy in the form of turbine shaft motion. The cross flow impulse turbine is built from two parallel circle disk combined together with a curved blade [9]. The water stream enters the runner blade until it touches the runner's edge, causing the turbine shaft to rotate [10].

The advantage of a micro-scale power plant is that it utilizes renewable energy, it is economical and efficient compare with most of energy technologies, has a high capacity factor, a slow rate of change, the power output only varies gradually from day to day [11]. Micro hydro plants can stand alone or in combination with other renewable energy. On the other hand micro hydro power plants are also low in cost, have a small scale sizes and can be installed to serve rural communities quickly. In general, micro hydro energy can be predicted, small power output can be easily adjusted, more reliable, low operating costs, durable technology and has no environmental impact [12].

The micro hydro power plants use only free water flow, low water flow rate and could work on a low head. It is very suitable to use cross flow turbines.



1. Air Venting Valve, 2. Distributor, 3. Turbine Casing, 4. Turbine Runner,

5. Removable Rear Casing, 6. Turbine Blades, 7. Water flow, 8. Turbine Shaft

Figure 1 Diagram of a Cross Flow Turbine

(Source :https://en.wikipedia.org/wiki/Cross-flow_turbine)

In accordance with the theoretical and field experimental studies, it was found that a cross flow turbine is driven by a water energy. After the observation, it is found that there were still many turbine blades were not pushed by the water jet, which means that there should be more potential energy if these could be pushed by the water jet. This phenomenon could reduce the turbine efficiency and it could not work optimally, as shown in Figure 1 above. It would cause a high vibration produced by the turbine rotation because the turbine rotation is not balanced, there is a high shaft vibration and the turbine power would. The turbine bearing on the shaft would damage on a short time. Furthermore, due to the turbine power reduced to drive the power plant, the turbine and electric generator life time could also be shortened [13].

Cross flow water turbines are impulse turbines that are more profitable than waterwheels because the cross flow turbine dimensions are smaller and more compact. Improving the a cross flow turbine performance by optimally utilizing water energy resources as a driving force for micro-scale electricity generation could greatly supports energy of a country's with clean development. [14]. The use of cross flow turbines can be utilized on the water energy potential that is naturally available in the natural surroundings. It is very suitable considering the type of cross flow turbine has an appropriate characteristic of a low head and small water flow rate. The water flow rate entering the cross flow turbine could be calculated [15], using the following equation.

$$Q = V.A \tag{1}$$

Description: V = Velocity of water jet from nozzle (m/s), A = Nozzle cross sectional area (m^2)

To find out the water power needed for a power generation, by implementing water energy, it is strongly influenced by the water flow rate and the water head energy, to convert the potential energy to be a hydraulic power [16]. The hpower input could be calculated using the equation as follows:

$$P_{Hydraulic} = \rho\, g\, H\, Q \tag{2}$$

Description: $P_{Hydraulic}$ = water input power into the turbine (Watt), ρ = water density (kg/m^3), H = head (m), Q = water flow rate (m^3/s) and g = gravitation (m/s^2).

The head height from the water level flowing into the turbine nozzle is measured at the point where the water jet from the nozzle provides energy in the form of water pressure from the nozzle. To find out the effective power produced by a cross flow turbine, the water energy received by the turbine blade is then converted into mechanical energy to produce a rotary motion on the turbine shaft which can be calculated by an equation as follows:

$$P_{Turbine} = (\text{Torque}) \times (\text{Turbine shaft angular speed}) = (\tau * \omega) \tag{3}$$

Torque could be calculated by multiplying between the centrifugal force and the turbine disc radius. While the angular velocity is the amount of rotation of the turbine shaft when the runner blade receives and converts the water energy into mechanical energy [17]. The turbine efficiency is a ratio between the effective power produced by the turbine, in the form of mechanical power as a driving turbine shaft, with the hydraulic power which is affected by the water flow rate and head. The turbine efficiency could be calculated as follows:

$$\eta_{Turbine} = \frac{P_{Turbine\ Output}}{P_{Water\ Input}} \tag{4}$$

2. EXPERIMENTAL SETUP

This research was conducted to test the effectiveness of a vertical nozzle and horizontal nozzle on cross flow turbines. The turbine size is under a laboratory scale levels to obtain a more optimal performance of cross flow turbines.

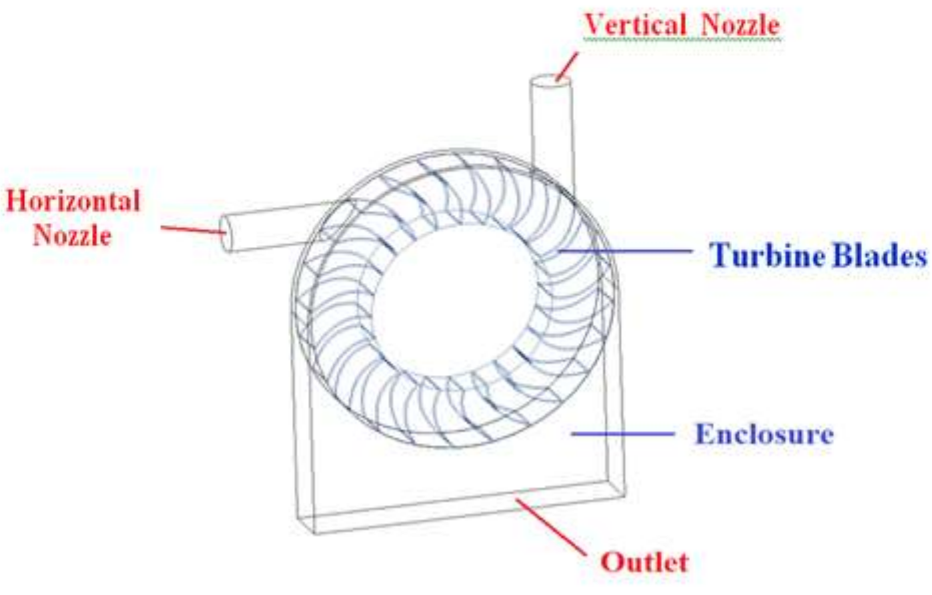


Figure 2 Cross Flow Turbine with a Vertical Nozzle and a Horizontal Nozzle

The material used in this study for the cross flow turbines tested is a transparent acrylic plate sheet. The turbine shaft is made from a steel, the vertical and horizontal nozzle is made from a plastic base material. The turbine holder and the whole installation body are made from an elbow steel profile. Another part of this installation is using plastic pipes, water supply regulator valves and a water storage tank

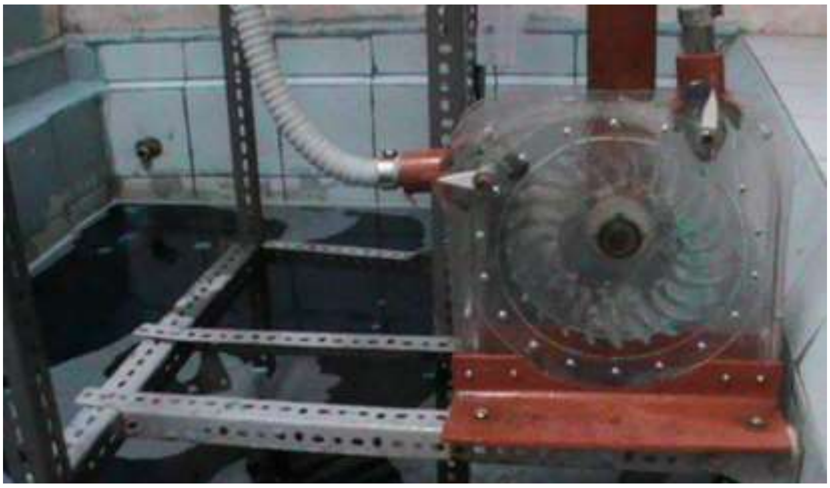


Figure 3 Cross Flow Turbine with Vertical Nozzle and Horizontal Nozzle (Experimental Setup)

Other instruments used in the study were the manometer, digital tachometer, dial gauge, digital flow meter, water pump, stopwatch, electrical stabilizer, an electrical regulator and a multi meter. The procedure for conducting the research is preparing the materials and equipment, installation, instrument calibration, testing, data collection, data analysis and conclusions

3. RESULTS AND DISCUSSIONS

As mentioned above that the experimental cross flow turbine was completed with a 12 mm diameter vertical nozzle and a 12 mm horizontal nozzle. The inside diameter turbine runner is 110 mm and the outer runner diameter is 200 mm. The runner width 40 mm, the blade thickness is 2 mm and number of blades 24 pieces. Based on the results of the study, a cross flow turbine completed with a vertical nozzle and a horizontal nozzle, on a free load, produces a maximum turbine rotation. After being given a load, the turbine rotation decreases in rotation along with turbine load increase [18], seen in Figure 4 as follows:

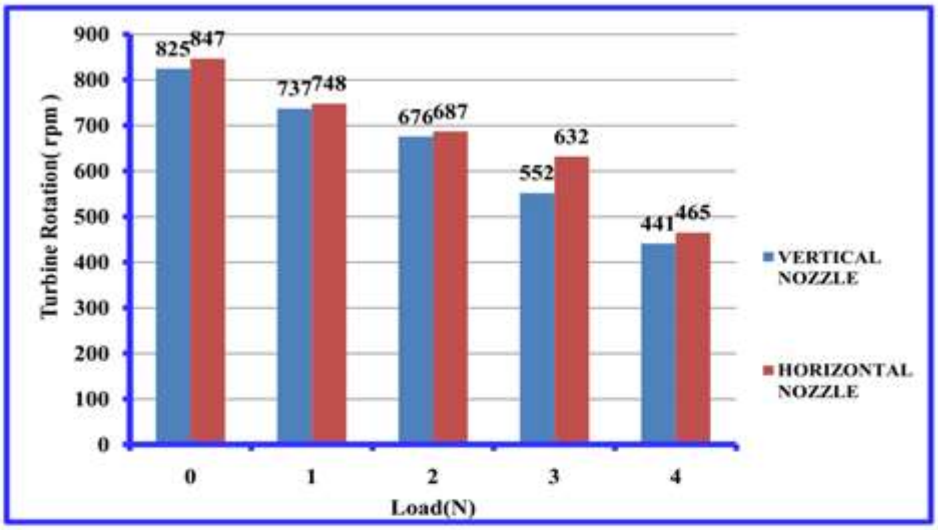


Figure 4 Turbine Rotation Vs Load

From Figure 4, it could be seen that a turbine with a vertical nozzle performance produces a lower turbine rotation with a 835 RPM and a lowest turbine rotation of 441 RPM. It is clearly happening because there is just one water jet that pushes the turbine blade. It means that just a small portion of the turbine blade was pushed by the water jet. The water jet was only moves vertically and the water is immediately wasted out of the turbine. While a cross flow turbine that use a horizontal nozzle produce a higher performance with a maximum rotation of 847 RPM and a minimum rotation of 465 RPM. The cross flow turbine with a horizontal nozzle can produce a larger runner rotation, because the water jets can push more turbine blades. The water stream would effectively push the turbine blade and rotate the turbine shaft. The effectiveness of the horizontal nozzle produces a fluid flow that effectively directs the flow of water to push the turbine blade and provides a large rotational motion on the turbine shaft [19].

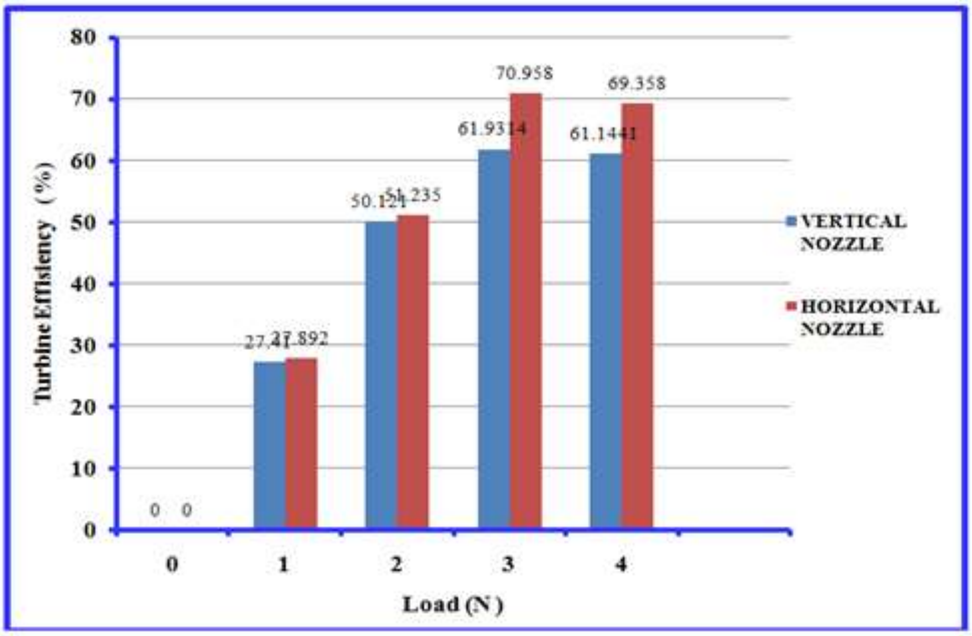


Figure 5 Turbine Efficiency Vs Load

In Figure 5, it is clearly illustrated that a cross flow turbine with a vertical and a horizontal nozzle, would give a higher efficiency either on a first low load or on the increasing given turbine load [20]. The cross flow turbine with a vertical nozzle has the lowest efficiency as big as 61.93%, while the cross flow turbine with a horizontal nozzle achieves a higher efficiency of 70.95%. The Cross flow turbine uses a horizontal nozzle have a higher efficiency because there is a high water speed on the blade outer end a circular manner and an angular momentum occurs so that the turbine output power would be higher. The water flow velocity through the runner blade has a greater effect on the turbine resulting in higher efficiency [21]. A cross flow turbine with a horizontal nozzle would get a higher water flow from the nozzle and evenly pushes or moves the blade and the water energy absorption by the turbine blade occurs twice. When the turbine reaches the optimum point load and the load continues to increase, a new phenomenon will occur, namely the turbine efficiency decreases due to the influence of the water jet cross sectional area widening, friction on the blade surface, which would causing a power loss and a turbine efficiency decrease.

4. CONCLUSION

Based on the research results, data analysis and the discussion, it can be concluded that a cross-flow turbine using a vertical nozzle are less effective because the turbine efficiency is lower compared with a cross flow turbine using a horizontal nozzle horizontal efficiency

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