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AnOuter Movable Blade Vertical Shaft Kinetic Turbine Performance

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Abstract

Although the complex problems experienced by large industry can be solved, the world is still suffering from a lack of energy. The problem is particularly felt in developing countries where people livein villagesand requires the development of a more efficient energy sources. The more expensive and limited fossil fuel, makes hydropower become the best energy source alternative.

It should be noted that the kinetic turbine that would be examined in this research is a vertical axis turbine type not a horizontal axis turbine. The reason choosing the vertical axis turbine is that the generator installation would be easier, the whole entire blade would get a boost push from the water flow, the whole turbine components installation would be easy too.

In this study the kinetic turbine to be examined is a turbine with a moveable blade which is installed on a hinge between the turbine discs. The long-term goal of this research is to provide a solution for rural communities so that they can build a simple but quite reliable power plant.

The research method used was an experimental method by varying the incoming flow rate, steering angle of the flow of water entering the turbine wheel and the turbine rotation. From this research an optimum result was reach for a vertical shaft kinetic turbine performance.

Keywords: Kinetic turbine, vertical shaft, movable blade.

Introduction

Indonesia has a great potential for new and renewable energy reserves, but it is not been implemented maximally yet. Hydroelectricity in Indonesia has reached about 4200 megawatts (MW), or about 5.5 percent of the existing water potential. The National Research Program priorities agenda in 2010 - 2014 in the field of alternative energy is an increase in the renewable energy micro-hydro utilization. The renewable energy potential status in 2009 [1] is that the new micro-hydro energy utilization is about 17.22% or 86 MW from 500 MW potential available.

Many studies has also been undertaken to improve the turbine performance, by speeding up the water flow by adjusting the turbine inlet dimensions, turbine shape and turbine blade size. The kinetic turbine performance depends on: water flow velocity, the blade angle, water flow steering, turbine shape, turbine blade size and number. The kinetic turbine blade number is one of the variables that affect the turbine force result and the angular velocity that determines the kinetic turbine power and efficiency. Increasing the number of turbine blades means increasing the amount of mass that would hit the turbine blades, but in adding the turbine blade number would allow for a reduction in the mass of the other blade portion.

Fullford et al. [2] conducted a research with a micro-hydro renewable energy sources from a small water flow rate (0.0087 m^3/s). From these results the power produced is about 2.34 Watt and an efficiency of 40.12%. Sornes K. [3] also examines a small-scale water turbine for river applications. According to this research, small-scale turbine for today is very reliable because it is environmentally friendly and a low cost project, long life and could help electricity supply for remote areas which was not reached by electricity yet. Hydrokinetic device placement, in relation to the turbine channel cross section is a very important component for the basic reason that the energy flux at the surface of the flow is higher than at the bottom of the river.

Soenoko et al [4] observing a dual wheel kinetic turbine prototype for the purpose of generating a simple power plants to support of procurement of electrical energy in remote areas. From the research result it is found that the torque produced by the dual wheel turbine is much larger than that in a simple water wheel turbine. From the research results it is also found that the maximum force load of this pair turbine runner occurred on a turbine rotation of 50 rpm between a water flow rate of 2 and 2.5 liter/s which is equal to 502 grams. Likewise Balaka et al [5] conducted a research on a water flow turbine with a vertical shaft type simulated on a Computation Fluid Dynamic (CFD) and experimentally. The purpose of this study is to obtain the force fluctuations caused by the changes in the turbine blade number and the turbine aspect ratio and to analyze the effects of torque ripple occurs. The result obtained by the experiment analysis is that with the turbine blade number addition the turbine rotation would increase. While from the simulation results it is found that the force generated under a low blade number has a slight less fluctuation. The best turbine efficiency generated by the turbine is equal to 54.6%.

Bibeau et al. [6] conducted vertical axis turbine kinetic research on a winter season. The total output during the winter test is much lower than expected because of blade design problems. Blade design studied in this research was the flat bar blade, profile blade, profile front blade and the hydrofoil blade. From the research the efficiency result for each blade shape is 15.9%, 28.8%, 29.1% and 35.4% respectively. So it is seen that the hydrofoil impeller design has the best result. Related research and design turbine blade design is also performed by Bisen et al. [7] which is a research on the power characterization of a Pelton micro-turbine by the blade shape variation. The result is that the power and efficiency characteristics of the turbine with a bowled bladed compared with the half cylinder bladed turbine is slightly the same, but the power and efficiency of the bowled bladed turbine is better than half cylinder bladed turbine. A research done by Chakraborty et al. [8] is about the blade number variation of a bowled bladed turbine compare with the single wheel kinetic turbine performance. From the results of the research showed that the turbine blade number would influence on single wheel kinetic turbine performance. The turbine with eight blades has the highest performance at a rotation of 80 rpm and generating a power of 22.775 Watt and turbine efficiency of 37.919%.

Takane l et al. [9] conducted a research on the water flow input angle variation of a bowled bladed kinetic turbine toward the turbine performance. The maximum kinetic turbine performance occurs at the water flow input angle of 10°, a rotation of 100 rpm, a power generated of 18 841 watts and an efficiency of 37.648%. Kaprawi [10] observed a vertical axis kinetic turbine based on blade geometry influences toward the turbine performance in order to obtain the best turbine performance. The blade thickness would affect the turbine blades strength, especially in retaining the drag on a small angle attack under a big force. The best blade thickness is difficult to be determined.

Nowadays, researcher is developing a kinetic turbine with an unfixed blade or moveable blade. The turbine blade could rotate on its axis which is rotating on a hinge. Some of which have been studied among others by Bo Yang et al. [11] which is conducting a research on a vertical axis kinetic turbine performance with a hinged blade called a Hunter turbine. The experiments were performed under flow visualization on small models to provide some basic movements of each blade in each position of the drum. A 2-dimensional CFD simulation was then used to obtain detail information about the flow field, including the pressure and velocity contours, also the pressure distribution on the blade surface. Bo Yang and Chris Lawn use blades made of semicircular steel plate. Each blade is attached to the shaft using a hinge. Monintja et al [12] analyzed the performance of the zero cross flow turbine head with some blade number variation (12, 6 and 4 blade) and the blade movement (blade hinged and fixed blade). The results showed that the best performance is obtained when the turbine blade number is 12 with a fixed blade. The optimum efficiency is about 0.47% and was obtained at a rotation of 89.9 rpm and generator output energy of 29.25 Watt.

In this case the research will be done to find out the vertical shaft kinetic turbine performance using a hinged blade mounted on the outside diameter of the disc. The hope to use this turbine is an increased of performance compared to a fixed blade kinetic turbine.

MATERIAL AND METHODS

Kinetic Turbine

A kinetic turbine is a turbine that is only relying on the water flow speed, so that this kind of turbine does not require a high water fall. This kind of turbine is very appropriate to be used on a flat area and has a watershed, especially for rural areas. Currently there are three types of kinetic turbines, ie flat kinetic turbines and upright kinetic turbine and horizontal kinetic turbine which is used in this study, the turbine is placed horizontally and the axis is placed vertically.

The equipment used in this study is:

1. Turbine Kinetic Runner
   Three main parts of a runner are the ST 37 steel shaft with a 30 mm diameter, a 355 mm acrylic disc diameter and eight pieces blades with a height of 10 cm a blade thickness of 4 mm made from acrylic material that is placed around the disc and move on hinges mounted on the outer diameter of the disc.
2. A plate barrier for the steering angle variation of: 15°, 25°, 35°, and a water flow rate variation of 35, 40, 45 and 50 m^3/h. The dependent variable observed in this study is the turbine power and the turbine efficiency.

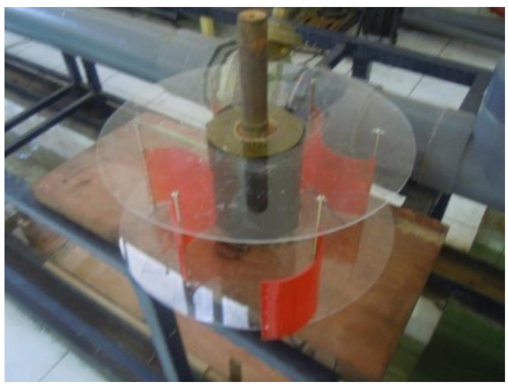

Figure 1: Turbine Blade Construction

Figure 2: Research Installation

Kinetic Turbine Power

The amount of energy produced by a water flow is determined by:

$$E_a = \frac{1}{2}.\dot{m}.V^2 \quad (1)$$

Where:

E_a = Energy water (Nm) or (Joule)

m = Mass of water (kg/s)

V = water velocity (m/ s)

For the power of water flow in a particular cross-section could then be calculated by:

$$P_a = \frac{1}{2}.\rho.A.V^3 \quad (2)$$

Where:

P_a = water power (watts)

ρ = Density of water (kg/m^3)

To calculate the turbine power generated due to the kinetic energy used is as follows:

$$P_t = T.\omega \quad (3)$$

Where:

$$T = F.l \quad (4)$$

$$\omega = \frac{2.\pi.n}{60} \quad (5)$$

With:

P_t = turbine power (watts)

T = Torque (Nm)

l = Arm (m)

n = turbine rotation (rpm)

F = Force (N)

Kinetic Turbine Efficiency

The kinetic turbine efficiency is determined by the ratio between the water powers entering the turbine with the power generated by the kinetic turbine, as shown:

$$\eta = \frac{P_t}{P_a}\ x\ 100\ \% \quad (6)$$

Where:

P_a = water power (watts)

P_t = turbine power (watts)

η = Turbine efficiency (%)

Result and Discussion

One of the turbine performance parameter is the turbine torque and turbine efficiency generated by the turbine. The torque measured on the torque pulley is equal to the torque produced by the turbine. The kinetic turbine performance test with a moveable (hinged) blade is made to obtain the turbine system characteristics. The experimental tests results to obtain the turbine with moveable blades characteristic is shown in figure 3, 4, 5 and 6.

In this study, there are three flow steering angle variations, 15°, 25° and 35°. In figure 3, the flow velocity and the highest turbine power graph, it was shown that the maximum power occurs at a flow steering angle of 25° under a flow rate of 1.1 m/s, which is as big as 19.91 Watt and the smallest power production occurs at a steering angle of 15° with a flow velocity of 0.8 m/s which is equal to 4.84 Watts.

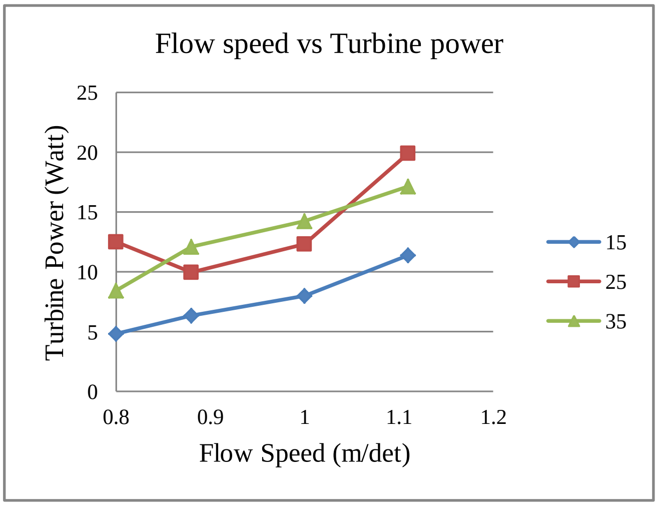

Figure 3: Flow speed vs Turbine power

Based on the graph in Figure 4 it is seen that with the flow velocity increased, the turbine efficiency tends to fall. In Figure 4, the flow velocity vs the highest turbine efficiency graph shows that the maximum turbine efficiency occurs at an angle of 25° with a water flow rate of 0.8 m/s, which is 38.15% and a lowest efficiency occurs at a water flow steering angle of 15° under a flow rate of 1 m/s, which is equal to 12.14%.

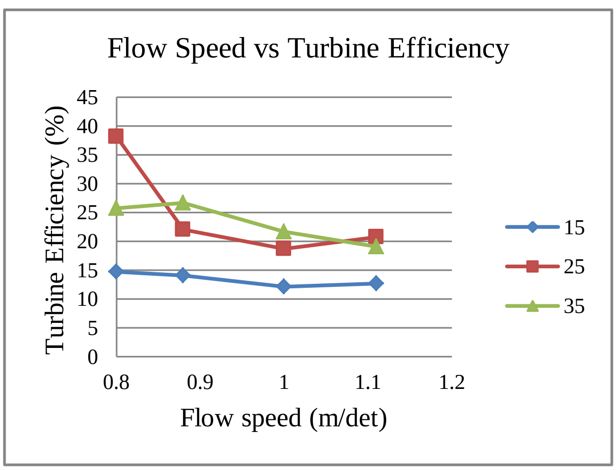

Figure 4: Flow Speed vs Turbine Efficiency

Based on the graph in Figure 5, it is shown that if the water flow steering angle increased, then the turbine power tends to rise. The highest turbine power occurs as big as 17.14 watts, under a water flow steering angle of 35° and a water velocity of 1.11 m/s, while the lowest turbine power occurs as big as 4.84 watts under a water flow steering angle of 25° and under a water flow rate of 0.8 m/s.

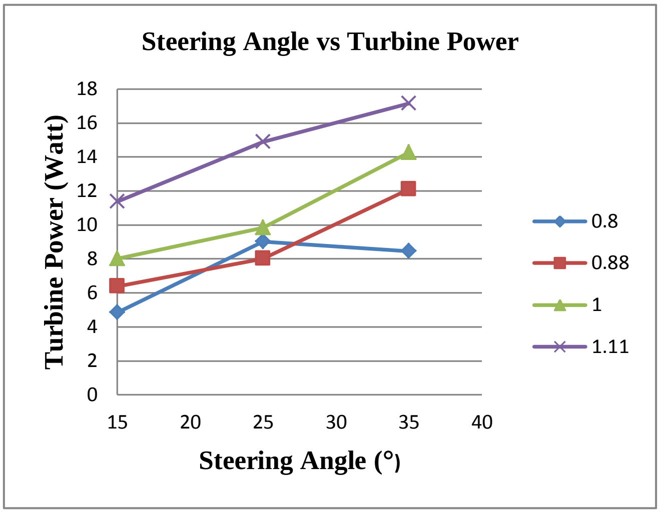

Figure 5: Water flow steering angle vs Turbine Power turbine

From Figure 6 it is seen that with the increase of water flow steering angle, the turbine efficiency tends to rise to the optimum level while the turbine efficiency is going down. From Figure 6, it is also shown that the highest turbine efficiency (which is 38.15%), occurs at a water flow steering angle of 25° and at a water flow rate of 0.8 m/s. While the lowest turbine efficiency (12.14%) occurs at a water flow steering angle of 15° and under a flow rate of 1 m/s.

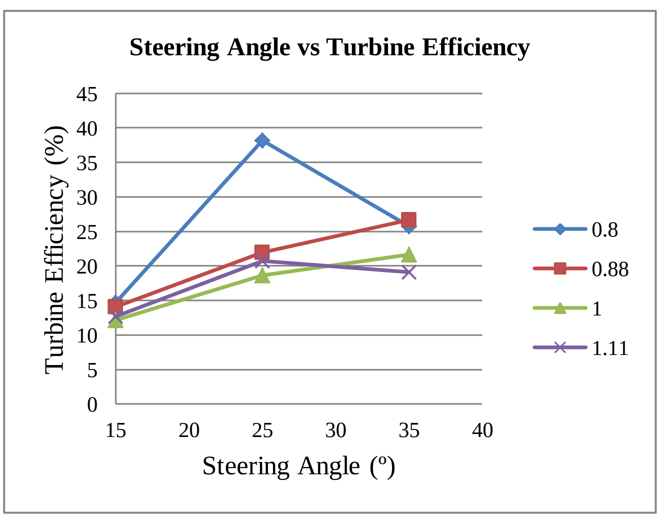

Figure 6: Water flow steering angle vs Turbine Efficiency

Compared with a fixed blade turbine kinetic which was done by Asroful [9], the moveable blade turbine kinetic has a better performance. This kind of turbine with a 8 blades equipped operated in a water flow rate of 35 m^3/h (0,01 m^3/s) under a 70 rpm turbine rotation could produce power as big as 19.91 Watt with a 38.15% turbine efficiency.

Another advantage of using a hinged blade turbine kinetic is that the water passing through the backward blade side would significantly push the blade to rotate the turbine wheel, while on the forward blade side the water flow could just pass through the turbine without any resistance from the blade, because the blade is under an open position.

Conclusion

After observing the hinged blade kinetic water turbine, it can be concluded that this kind of turbine has a better compared to the fixed blade kinetic turbine.

In this study the optimum water turbine efficiency is about 38.15% under a 25° water flow steering angle and produces an electric power of 19.91 watt.

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