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The Influence of Flow Steering Angle on the Performance a of Cup-Bladed Kinetic Turbine

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ABSTRACT

Basically, alternative energy sources will never run out in the future. Alternative energy sources provide energy wherever it is required, and convert energy from one form to another without causing pollution which can harm the environment. One of the alternative energy sources with in Indonesia is flowing water in rivers which contain huge potential of kinetic energy. If the water flow rate could be harnessed optimally for producing kinetic energy, the problem of energy crisis could be overcome. Therefore, it is important to figure out the way of improving the performance of cup-bladed kinetic turbine by varying the angle of steering flow. The objective of this research is to study the influence of flow steering angle on the performance of cup-bladed kinetic turbine. This research uses experimental method and conducts in laboratory scale. The tested kinetic turbine is limited to the flow streering angle with 8 blade, cross-sectional area of channel of 0.26 x (0.1 and 0.12) m^3, the turbine axis diameter of 110 mm, length and with of the blades, consecutively are 13 and 12 cm, flow steering angle is varied by 15^o, 25^o, and 35^o. Kinetic turbine works in stable rotation and the stability of rotation is required to produced better quality of electricity. The observation results show that the flow steering angle influences the performance (power and efficiency) of kinetic turbine.

Keywords: water energy, energy potential, kinetic turbine

INTRODUCTION

Water energy can be used as power generator by harnessing the available potential power specifically potential of waterfall and flow rate). Indonesia has large potential to develop hydroelectric power plants because of the topography of Indonesian lands which have many montains and hills with many rivers; moreover, certain areas have lakes and reservoirs as water resources. Hydroelectric power plant has been proven using environmentally benign technology, supporting energy diversification as the utilization of renewable energy, and supporting the reduction of fossil fuel use program; furthermore, most of the construction of a hydroelectric power plant using local material. Based on the National Energy Management blueprint [1] the water energy potency is about 75,670 MW and was just 4,200 MW harvested or about 5.5 %. As much as 70,776 MW lies outside Java Island. For the micro hydro potency it is about 458.75 MW and was just 84 MW implemented, which is just about 18%. Data from the Indonesian Energy and Mineral Resources Department [2] says that until di end of 2008 the total capacity of the electric power generated is just about 30.527 MW. Besides large hydroelectric power plants, minihydro with capacity of 200 – 5,000 kW have potential to generate 458.75 MW; therefore it is really worth developing in order to meet the need of electricity in rural areas that have small rivers.

Potential energy from water, especially from rivers, is very large. The flow rate of the water will generate kinetic energy. If the flow rate can be well utilised, energy crisis in Indonesia can be solved. Cup-bladed kinetic turbine is used in this research. One of the advantages of the cup shape of the blade is the sides of the blade can hold water so that most of the flow rate can be utilised to drive the turbine. Kirke Brian [3] developed kinetic turbine by conducting research expecially vertical axis kinetic turbine. The main concern in every Brian's research is how to improve the efficiency of the vertical kinetic turbine. Plenty of effort has been done, among others by adding insulation to the inlet of the turbine so that the back of the turbine which rotates backwards can avoid water pressure. Another effort by Brian was by tilting the turbine disc to optimize the calculation of velocity triangle and the turbine reverse blade will not get reverse pressure from the water flow. In other research that varies the blade's shape and also varies the inlet angle of water flow rate to the turbine, the efficiency of the turbine could be increased by 38%.

Bono and Indrato [4] conduct a research and conclude that the characteristics of power and efficiency between cup blade and half cylinder turbine are almost the same, but power and efficiency of a cup blade turbine is better than the half cylinder blade turbine. Flow steering angle of kinetic turbine determine turbin rotation where flow steering angle is not always linear with the increase of turbin rotation. For that reason, this research is aimed at determining the ideal flow steering angle with constant velocity in delivering maximum rotation. The objective of this research is to discover the influence of flow steering angle on the performance of a cup-bladed kinetic turbine.

Warsito et al [5], conducting a research by analyzing the nanohydro renewable energy sources from a small water flow (0.0087 m3 / s). The result of this research is a 2.34 Watts power generated and an integral system efficiency of 40.12%.

MATERIALS AND METHODS

This research using water flow from river as the main object by considering the moving fluid flow has massive kinetic energy. Water kinetic turbine is a form of water turbine which only utilizing flow rate and does not requiring nozzles; moreover, this kind of turbine does not need a casing. The kinetic turbine that is used in this research is an Overshot type with flow steering angle varies by 15°, 25°, dan 35°. The research variables are

- Independent variable: flow steering angle varies by 15°, 25°, dan 35°
- Dependent variables: power and efficiency.

Previous research

David L. F. Gaden [6] conducted research about modelling turbine that observes the turbulence which occurs at a kinetic turbine. In his research, the observed turbine was a propeller kinetic turbine whose axis parallel with the water flow into the turbine. The kinetic turbine was given a flow pattern that forms a flow from a small section channel then expands with diameter ratio fourfold greater (D = 4d). The distance between the flow in smaller section and the larger flow section is 12 d. The distance is determined according to the calculation of flow rate change to fourfold greater and turbulence does not occur yet. The flow form with section ratio under 1:4 will cause turbulence. Consequently, turbine's blade experiences back pressures, and the rotation of the turbine will decelerate; as a result, the efficiency decreases. Need to remember that a kinetic turbine operation depends on water flow rate (kinetic energy = $v^2/2g$).

Ariadi H et al [7], conducted a research on a vertical axis water flow turbine by a Computation Fluid Dynamic (CFD) simulation process and experimentally. The purpose of this study is the get the force fluctuations caused by the blade number and turbine blade aspect ratio to analyze the effects of torque ripple. The result, from the experiment analysis, is that increasing the turbine blade number will increase the turbine rotation. While from the simulation results, the force fluctuation generated by the turbine with less blade number has a slightly less fluctuation. The best turbine efficiency generated by the turbine is equal to 54.6%.

Santoso et al [8], conducting a research on a vertical shaft cross-flow water turbine by implementing a helical blade design. The main purpose of this study is to demonstrate the ability of the water turbine with helical blades in extracting useful energy from a water flow. From the experimental study on the turbine prototype, it is found that turbine efficiency is as big as 17% and the maximum power generated is 17.98 Watt at a 1.2 m/s flow rate.

David L. F., Gaden and Eric L. Bibeau [9], conducted a research on a vertical axis kinetic turbine to improve the turbine performance by designing the turbine arm shape (flat bar, profile, front profile, and hydrofoils). The efficiency research result for every arm shape is 15.9%, 28.8%, 29.1% and 35.4%.

Soenoko et al [10], conducted a study to determine the performance of the double kinetic turbine wheel prototype as a rural power generation. The purpose of this study is to minimize the water flow back pressure. From this study it can be concluded that the maximum force of the second load runner discharge occurred on 2 and 2.5 liter / second, which is equal to 502 grams at 50 rpm and power generation of 134 Watt.

Kinetic Turbine

A kinetic turbine is a turbine that only depends on water flow rate. So, a kinetic turbine does not need a head energy. This turbine is very suitable to be used in plain areas that have rivers. To date, water wheel is a type of kinetic turbines that has been widely known. A water wheel is a very simple type of kinetic turbines which still can be found in Indonesia, e.g. water wheel in Pronojiwa, Lumajang, which is used to power a small generator to charge batteries of vehicles. In Jurang Banteng village at the foot of the Mount Kelud, Blitar, a water wheel is used to drive coffee processing equipment (milling, paring, and sieving) In Mojopanggoong, Tulungagung, a water wheel is used as rice pounders. There are still more regions in Indonesia that familiar with water wheels.

As mentioned previously in the introduction, the kind of water wheel that is used in Indonesia is an Overshot type. The efficiency of water wheels in Indonesia is low. One of the causes is that the wheel is made of wood, and not precisely constructed; accordingly, many leaks occur.

Nowadays, there are three kind of kinetic turbine, namely flat kinetic turbine, vertical kinetic turbine, and hollow kinetic turbine. The type of turbine used in this research is the flat one where the turbine is placed horizontally and its shaft is lain vertically, so it is called axial turbine.

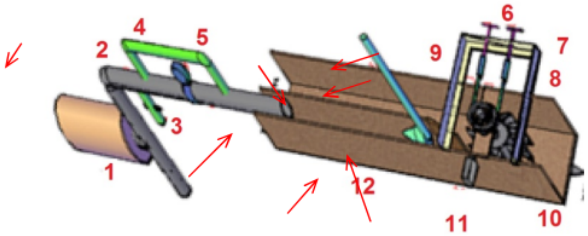

Figure 1 Research Instalation

1. Pump
2. Pipe
3. Valve
4. Bypass Pipe
5. Flow meter
6. Variable Loader
7. Scale
8. Wire
9. Pulley
10. Runner
11. Water Duct
12. Flow watch

Cup Blade

Cup blades are blades with curved sides so that can hold more water flow and increase the efficiency of tangential force. This research uses cup-shaped blade with hinges to reduce back force from water flow. A cup blade is shown at Figure 2 below.

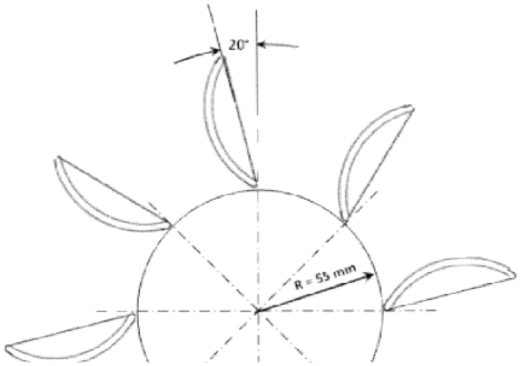

Figure 2 Cup Blade

Triangle Velocity

Triangle Velocity is frequently used in determining the parameters in a turbine design in order to determine the shape of the turbine's blade at every point of change. The triangle velocity at every point of change has a different form in accordance with the moving flow rate.

There are three components in a triangle velocity. First is the tangential velocity (*u*) that is the velocity in the direction of rotation of a rotor. Second is the velocity of water flow or absolute velocity (*v*). Lastly, is the relative velocity of water to the blade.

Two important forces that very important in velocity analysing are: tangential and axial force in velocity triangle. These forces are required to calculate the torque produced. The power of the turbine can be found by multiplying torque by rotation. Velocity triangle is shown in the Figure 3.

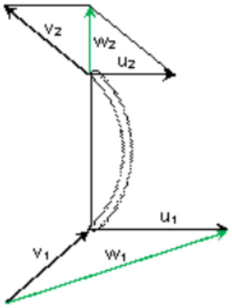

Figure 3 Triangle Velocity Components

Research Equipment

Equipment and materials used in this research are

1. **Kinetic Turbine's Runner** A runner consists of three main parts, that are

turbine's shaft, turbine's disc (made of steel, with diameter of 110 mm), and three flow steering angles: 15°, 25°, and 35°, made of 4 mm thick acrylic.

2. **Steering channel of water flow** Steering channel used in this research is made of wood plate 3 cm thick, and height of 25 cm, with sectional area of 250 cm x 55 cm.
3. **Tachometer** Tachomenter is used to record the phenomena of the turbine rotation and the flow form occurs around the turbine.
4. **Flowmeter** Flowmeter is used to measure the velocity of the water getting in the turbine.

The performance is the property shown in the equipment that involve independent variables (operational indicators) and dependent variables (performance indicators). The independent variable in this research is flow steering angle, and the dependent variable is efficiency.

The formulas used in the analysis are

Water power:

$$P_a = \frac{1}{2} . \rho . Qa . V^2 \qquad (1)$$

where :

P_a = water power (watt)
ρ = water density (kg/m^3)
Q = volume flow rate (m^3/s)
V = water velocity (m/s)

Turbine power:

$$P_t = T . \omega \qquad (2)$$

where:

T = torque (Nm)
ω = angular velocity (rad/s)

Efficiency:

$$\eta = \frac{P_t}{P_a} x\ 100 \qquad (3)$$

where:

P_t = turbine power (watt)
P_a = water power (watt)
η = efficiency (%)

Torque:

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

where:

F = total force, (F_1 - F_2) (N)
L = length (0.15 m)

Flow rate:

$Q_3 = A_3 . V_3$ (5)

where

Q = flow rate (m^3/s)
A = cross-sectional area (m^2)
V = water velocity (m/s)

Ratio of blade's tangential velocity:

– — (6)

where:

U/V = Ratio of tangential velocity to water velocity
R = radius of turbine

Momentum:

(7)

where:

M = momentum (kg.m/s)
β = angle between w and u
Q = flow rate (m^3/s)
= water density
V = water velocity (m/s)

RESULTS AND DISCUSSION

The results of examinations in this research on the influence of flow steering angle variation and flow rate to the performance of cup-bladed kinetic turbine can be seen in Figure 4 below.

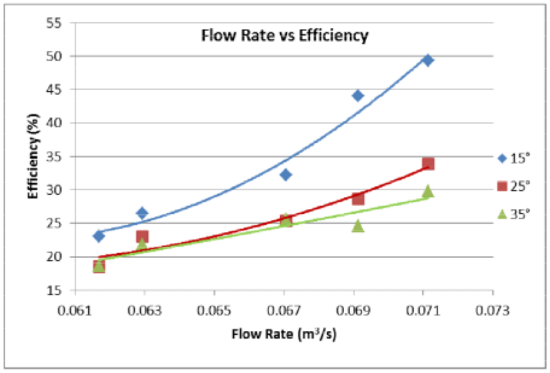

Figure 4. Flow Rate vs. Efficiency Graph

Figure 4 shows that the maximum efficiency occurs when the angle of flow steering is at 15°. Smaller flow steering angle will cause higher momentum. Accordingly, the torque increases. The results of data processing on the test of the flow steering angle influence to the kinetic turbine performance show that at the angle of 15°, the kinetic turbine reaches its maximum efficiency of 51%. This happens because energy from the velocity of water flow into the turbine is more utilized because water pound exactly on the frontage of the turbine's blade.

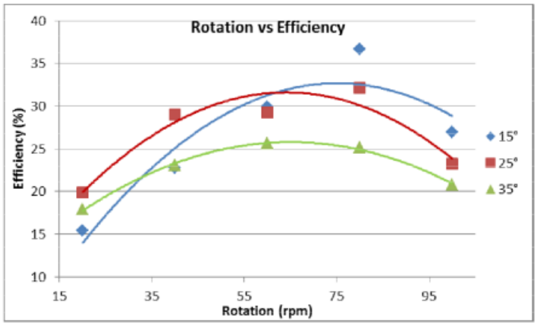

Figure 5 Rotations vs. Efficiency Graph

As can be seen in Figure 5, rotation also influences the performance of the turbine. The maximum efficiency is 51% occurs at 80 rpm.

CONCLUSION

From the results of this research, it is concluded that the flow steering angle influences the performance (power and efficiency) of a cup-bladed kinetic turbine. From the test results, maximum energy (51%) can be reached at the angle of 15°. Angle of 25° and 35° give an efficiency of 33% and 30%, consecutively.

SUGGESTION

This research can still be continued with smaller angle (less than 15°), because the bigger the angle, the smaller the efficiency.

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