Outer Hinged Blades Vertical Shaft Kinetic Turbine Flow Pattern Visualization

Silvy Dollorossa Boedi, Rudy Soenoko, Slamet Wahyudi, Moch. Agus Choiron

Abstract: The Micro hydro power plant (MHPP) development can be used to supply electricity to people living in remote areas. Because the electricity needed in this area is usually not too big. In remote areas and located far from the electricity transmission network, electricity supplies from small capacity power plants is needed, especially those that utilize renewable local energy potential. The energy utilization as electricity generation is by utilizing available kinetic energy (water potential and water flow speed). The research carried out experimentally and then optimized with Response Surface Methodology. The optimization results are then tested again so as to obtain verification results from the optimization value.

Furthermore, based on the value of optimization, visual observations are made to see the flow behavior that occurs on the outside hinged blade and turbine chamber. From the visual observations, it was found that not all the water flow hit the turbine blade surface. On the blade back side, the water flow that hits the turbine blade will increase the turbine rotation. On the blade front side, the water flow that hits the outer blade will open the blade and the water flow will come out immediately from the turbine so that it will reduce the negative torque or back rotation.

Keywords : water flow energy, kinetic turbine, outer hinged blade, visual observation

I. INTRODUCTION

Indonesia has a mountainous and hilly topography and is drained by many small and large rivers, and in certain areas there are even lakes and reservoirs which are quite potential as water energy. North Sulawesi Province has four river areas, namely the Sangihe Talaud, Tondano Likupang, Dumoga Sangkup and Poigar Ranoyapo river areas, but the use of electricity in North Sulawesi has not been maximized the existing hydro-power potential.

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The water energy utilization as an electric energy generator that is by utilizing the water potential energy and the water kinetic energy available both from waterfall potential and from the water flow velocity.

The observed kinetic turbine in this research was inspired by a water-wheel. The waterwheel gets the energy based on the water weight entering the wheel blade. Based on this water-wheel came up with the idea to make a kinetic water turbine, which is a horizontal water-wheel turbine, which is immediately dipped in a river flow current with an upright (vertical) turbine shaft. Research by making a prototype of a double wheel kinetic turbine with the aim to produce a simple power plant in supporting the procurement of electrical energy in remote areas. In this research it is shown that the torque produced by this turbine is much greater than the turbine shaped water wheel [1].

Likewise, research with a nano-hydro renewable energy sources from a small-flowing water flow (0.0087 m^3/s). From the results of the study the power generated was 2.34 Watt and the efficiency value was 40.12% [2]. There are also other studies on small scale hydro turbines for applications in rivers. Small-scale turbines today are very reliable because they are environmentally friendly, inexpensive, long-lived and help supply electricity to remote areas that are not afforded by the national electricity network [3]. Along with the many developments in research on kinetic turbines using a fixed blade, now research is directed at kinetic turbines using a non-fixed blade or blade using a hinge. What has been investigated, among others, is by Bo Yang, conducting research on the performance of a vertical axis hinged turbine called as a Hunter turbine. Experiments are carried out by flow visualization on a small model to provide some basic movement of each blade in each drum position. The 2-dimensional CFD simulation is then used to obtain detailed information about the flow field, including pressure and velocity contours, as well as the pressure distribution on the blade surface [4]. Bo Yang and Chris Lawn used blades made of semicircular steel plates. Each blade is attached to the shaft using a hinge and in its research varies the height of the blade [5]. The study was also conducted to see the performance of zero head cross flow turbine with varying number of blades (12, 6 and 4 blades) and blade movements using fixed blades and hinged blades. The results showed that the best turbine performance was obtained when the number of blades was 12 with constant blade motion. The optimum efficiency of 0.47% is obtained at a generator rotational speed of 89.9 rpm and the generator output energy of 29.25 Watt [6]. Subsequent research on further exploration, which is the development of a micro turbine called a kinetic turbine [7].

The research development is continued by observing the hinged blade turbine water turbine, and it can be concluded that this type of turbine has a better performance than the fixed blade kinetic turbine.

In this study the water turbineoptimal efficiency is around 38.15% with a directional flow of 25° and produces 19.91 watts of electrical power [8]. Some researchers conducted research to improve the kinetic turbine performance, including observing the directional angle effects of kinetic turbine flow with a blade [9]. Further research is to determine the prototype of a double wheel kinetic turbine as a rural power plant to minimize backflow, the results showed that the maximum load that occurs in the second runner occurs at a flow rate of 2 L / s and 2.5 L / s [10]. Investigation on a Savonius water turbine to get the turbine performance by using one and two directing plates, this directive serves to direct the water flow directly to the right [11]. The performance of vertical shaft kinetic turbines with hinged blades is also observed and analyzed, by looking at the water flow behavior in the turbine chamber, to find out the constraints of the performance of this turbine [12]. This turbine design is very simple and can be made and used in remote areas. The study was also carried out to obtain the maximum performance of a Turgo Pico-Hydro turbine using a single jet and a low head turbine of 3.5 m to 1 m [13]. The savonius turbine performance is modified using two directional plates to direct the flow of water to the turbine straight ahead [14]. Another kinetic turbine study was also carried out with a CFD modeling, in which the highest kinetic turbine efficiency was obtained at a value of 19% and at a water flow rate of 45 m^3/hour and a turbine rotation of 80 rpm [15]. Research to observe the more optimum kinetic turbine performance was carried out using Response Surface Methodology [16], [17], [18].

II. MATERIAL AND METHOD

The turbine that has been observed in this research is the outer hinged kinetic turbine, which has been tested for the performance in the Fluid Mechanic Laboratory, Engineering Faculty, Brawijaya University, Malang. All parameters related to the turbine performance are recorded, such as the flow direction, blade number, water flow rate, turbine rotation and torque. Runners include, an ST 37 steel shafts with a 30 mm diameter, 355 mm disc diameter with an acrylic material, with a 9 cm high blade and 3 mm thick acrylic material that is mounted around the runner and moves on hinges mounted on the outside diameter of the runner. As shown in Fig. 1.

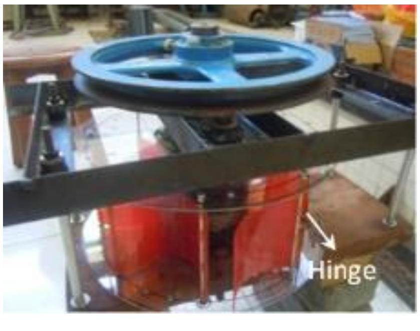


Fig. 1. Outer hinged kinetic turbine

The research will be carried out experimentally on a laboratory scale and the laboratory results will be optimized with the Response Surface Methodology. The purpose of optimization is to determine the behavior of water flow in the outer hinged kinetic turbine and evaluate the performance of a more optimal water turbine.

Outside hinged kinetic turbine to be tested in a laboratory has a number of equipment to support the research topics on turbines.One of the equipment used in this study, is a test bed turbine equipped with a pump with a capacity of 1.5 m^3/h placed in the test installation as shown in Fig. 2.

Fig. 2. Research Installation

To get the turbine torque data, the braking system equipment is mounted on the turbine shaft, the turbine rotation measurements are also carried out with a tachometer, as shown in Fig. 3.

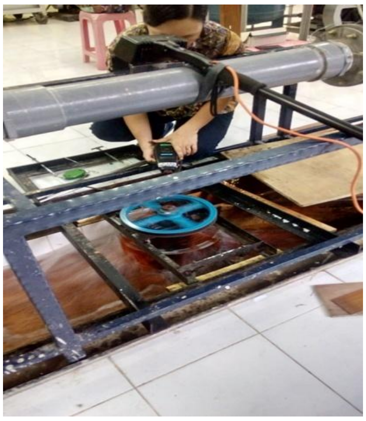


Fig. 3. Braking System and Tachometer

In this study, the outer hinged kinetic turbine is submerged in the channel, its size is limited by the channel cross section. To further maximize the turbine rotation, a flow guide is installed so that water enters the turbine blade directly, Fig. 4.

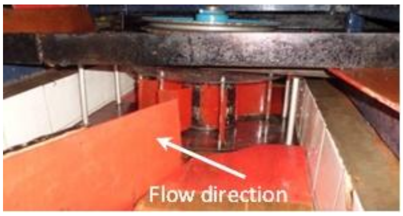


Fig. 4. Flow Guide

As mentioned above, the performance of this outer hinged kinetic turbine has been tested under several conditions and variations in parameters. Furthermore, optimization has been done using Response Surface Methodology, so as to obtain an optimal turbine model which is the novelty in this study. Further research is carried out to see how the blade moves and how the water moves in the turbine space. The implementation of this research is to take video images as long as the turbine operates at an optimal turbine performance condition.

III. RESULT AND DISCUSSIONS

The behavior and movement of water flow in the turbine blade in the turbine chamber will be recorded in the form of video recordings. Then the video recording will be broken into several images, according to the time sequence in the video capture. In Fig. 5, are examples of some images that are converted from video to images. The optimal conditions, according to the results from the Response Surface Methodology after the verification, the blade number is 15 blades, the directional angle of flow is 33° and a flow rate of 48 m^3/hour.

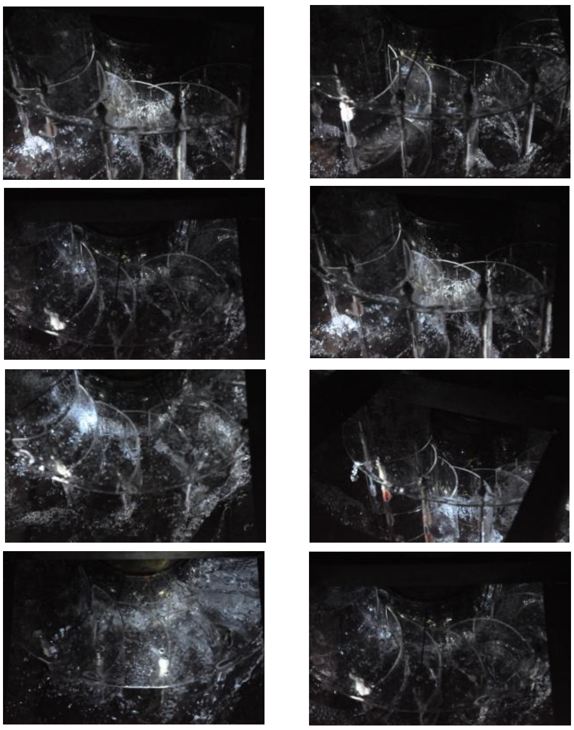


Fig. 5. Outer hinged blade and the water flow hit the blade

From the picture above, it can be seen that each blade and the water flow movement hit the blade. To get a clearer figure on how the water flow behavior hitting the blades, a schematic image could be seen in Fig. 6.

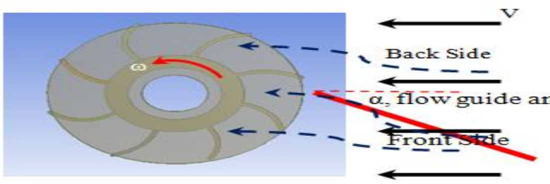
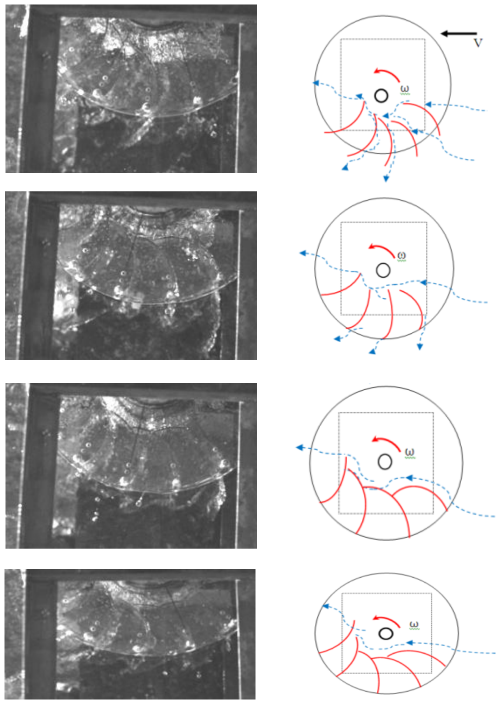


Fig. 6. Outer Hinged Blades Kinetic Turbine and Flow Direction

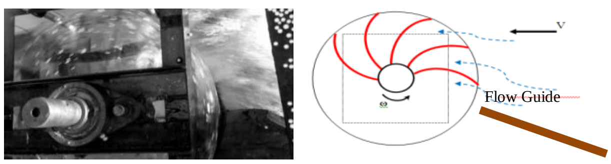
The outer hinged turbine will rotate if given a certain flow-rate and flow velocity. The flow of water will hit the blade on the front side and the blade on the backside. On the blade front side, Fig. 7, the flow of water that hits the hinged blade will force the blade to open and the water flow will freely leave the turbine area, so there is no negative torque. On the turbine blade back side (Fig. 8.), the water flow that hits the blade would force the blade to open and would result a turbine spin.



(a) (b)

Fig. 7. (a) Flow behavior on an open forward blade (b) An open forward blade scheme

It could be explained that the water flow will push the turbine blade from the front side so that the blade will open and the flow of water will immediately come out from the turbine. At the beginning of the turbine rotating due to the push of water, there is still a flow of water that comes out through the blade front side and until a certain time the water flow does not come out again and the turbine rotation would be stable. If the turbine blade is not yet open or there is still a gap for the outflow of water, then the outflow of water is likely to give a back pressure effect on the turbine rotation, so that the turbine rotation will decrease. After a certain time, the turbine will reach a stable rotation position, because on the blade front side, the blades are all open and pressing one blade to the other blade.



(a) (b)

Fig. 8. (a) Flow behavior on a blade back side (b) Water flow behavior on the blade back side scheme

It can be explained that the flow guide on the blade back side would guide the water flow hit the turbine blade and surely would increase the turbine rotation. This happens because the flow guide will function like a nozzle, where there is a difference in the flow guide cross-sectional area when the water flow enter the turbine area. The difference in the guide flow cross-sectional area goes to the turbine blade back side, will change the flow speed that will hit the blade back side. The water flow velocity after passing through the flow guide will increase so that the turbine rotation will increase as well..

IV. CONCLUSION

Based on the flow behavior scheme, the development of a vertical shaft kinetic turbine using a hinged blade mounted on the outer side of the turbine runner provides benefits on the backward side, with the flow guide driving the turbine to rotate more stable so as to provide a positive torque, thus the turbine performance (power and efficiency) can increase and on the forward side will eliminate the negative torque, because with the opening of the blade there will be no back pressure so that it will provide a positive torque, turbine performance (power and efficiency) can be increased.

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