Design and Construction of Kinetic Turbine External Hinged Blade as A Picohydro Scale Power Plant

Silvy Dollorossa Boedi, Josephine Sundah, Meidy Kawulur, Franklin Bawano

***Abstract**: The problem of energy shortage is still a global problem which is especially felt in developing countries whose residents live in villages, which still require the development of more efficient energy sources. Limited fossil fuels make water energy the best energy option. The problem of meeting the availability of electricity in rural areas by utilizing water energy as new and renewable energy is a long-term goal in this research. The current research on kinetic turbines is a combination of two types of waterwheels, which have a vertical axis (overshot and swell turbines). The vertical shaft is made so that the generator is easier to install and all the blades get a boost in the flow of water. Most water turbines have fixed blades. In this research, the target of the novelty is a kinetic turbine with a vertical shaft which has a hinged blade. Hinged blades are blades that can move when the flow of water hits the blades, so that on one side of the turbine it will reduce the negative torque and on the other hand it will increase the rotation of the turbine. The results of the research that became the target, namely, obtained a turbine design that has more optimal turbine power and efficiency, compared to a turbine that has a fixed blade, so that this externally hinged blade kinetic turbine can contribute to the provision of rural electrical energy. This research method is an experiment by doing independent variations on the number of blades, and blade 10 has an optimum power value of 59.01 Watt.*

***Keywords**: Turbine; Kinetic; Blade; Outside Hinged*

I. INTRODUCTION

The potential of renewable energy reserves in Indonesia has not been maximally utilized. The new hydropower potential is 4200 MW, which means that only about 5.5% has been utilized. The priority program of the 2010 - 2014 national research agenda in the field of alternative energy is to increase the use of micro-hydro renewable energy. Data for 2009, the micro-hydro energy used is only around 86 MW or 17.2% of the potential source of 500 MW. Although the serious problems experienced by industry in developed countries can be found solutions and overcome, we are still faced with the problem of energy shortages, especially felt in developing countries, where people who live in villages need the development of energy sources that are cheaper and more efficient. The more difficult and limited fossil fuels, making the potential of water the best energy alternative. As many as 19 million people do not have electricity, especially for areas in Eastern Indonesia that are far away. In areas that are far from the PLN electricity transmission network, small-scale power plants are urgently needed to meet the electricity needs of the community, by directly exploring the energy potential that exists around the residence, especially those that are renewable energy.

It turned out that the community had difficulties in building their own PLTM. Another problem that arises is, if the PLTM already exists, maintenance problems and various problems that arise are related to the PLTM installation as a whole. For example, bearing damage due to water splashing into the bearing, causing bearing damage. It has also happened that generator generators were treated incorrectly so that they were damaged and could not generate electricity. Warsito conducted research by realizing and analyzing energy sources from water flow (nanohydro) which has a discharge of 0.008 m3/s, with a head height of 1.5 meters using a Francis type mill [1]. The results of the study noted that the power generated was 2.34 Watt and the integral system efficiency was 40.12%. Likewise with Sornes K, also researching small-scale water turbines for applications in rivers. According to him, small-scale turbines are currently very reliable because they are environmentally friendly and inexpensive, have a long life and help supply electricity in remote areas that are not yet covered by electricity. The placement of the hydrokinetic device, in relation to the channel cross section, is a very important component for the basic reason that the energy flux at the surface of the stream is higher than at the bottom of the river [2]. Various studies have also been carried out to improve the performance of vertical shaft turbines, namely adjusting the dimensions of the turbine inlet to accelerate the flow, as well as adjusting the size and shape of the blades. Soenoko, made a kinetic turbine model using 2 wheels (double wheels), the goal is to make it a small/simple power plant that will benefit the provision of electrical energy, especially in areas far from PLN electricity [3].

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***** Correspondence Author (s)

Silvy Dollorossa Boedi*, Lecturer, Department of Mechanical Engineering, The Manado State Polytechnic, Manado, Indonesia. E-mail: silvyboedi@gmail.com, ORCD ID: https://orcid.org/0000-0003-3965-3730

Josephine Sundah, Lecturer, Department of Electrical Engineering, The Manado State Polytechnic, Manado, Indonesia. ORCD ID: https://orcid.org/0000-0003-1098-7980

Meidy Kawulur, Lecturer, Department of Mechanical Engineering, The Manado State Polytechnic, Manado, Indonesia. ORCD ID: https://orcid.org/0000-0001-7391-7360

Franklin Bawano, Lecturer, Department of Mechanical Engineering, The Manado State Polytechnic, Manado, Indonesia. ORCD ID: https://orcid.org/0000-0002-7878-0620

In his research, turbines using 2 wheels have greater torque than water wheel turbines. The optimum force of 502 grams, 50 rpm and a discharge between 2 – 2.5 liters/second occurs on both 2 wheel turbines.

Another research was also conducted by Ariadi, research with CFD simulation and experimental was carried out for vertical shaft type water flow turbine [4].

This research is expected to obtain results from the rise and fall of the force caused by variations in the addition of the number of blades and the aspect ratio of the turbine, as well as to obtain an analysis of the resulting torque. Based on experimental analysis, with variations in the number of blades, turbine rotation will increase with the addition of the number of blades on the turbine, while based on CFD simulations depicting the rise and fall of the force value is influenced by variations in the number of blades, a few blades will get a small fluctuation value as well, optimal turbine efficiency is 54.6%. Bibeau, conducted research on vertical shaft kinetic turbines. Based on the results of his research, the optimal efficiency of the turbine is 35.4%, the turbine performance can be improved with the hydrofoil arm model [5].

Bono concluded, variations in the shape of the blades on the Pelton turbine, that the shape of the bowl and semi-circular blades have almost the same turbine power, but the efficiency of the bowl blades is higher than the semicircular blades [6]. Turbine performance depends on flow rate, flow velocity, turbine rotation, flow direction angle, blade geometry and the number of blades, where the number of blades is a variable that affects the performance (power and efficiency) of the kinetic turbine. Increasing the number of blades means that the amount of mass hitting the turbine blades increases, but increasing the number of blades allows for a reduction in the mass of some other blades. Several studies on vertical shaft kinetic turbine blades were carried out by Ohoirenan [7]. The research was conducted on a turbine that has a single wheel, by varying the number of blades in the bowl blade model. Turbine with 8 blades works more optimally with 80 rpm rotation, 22.7 Watt power and 37.9% efficiency. Likewise with Yani, variations in blade length were investigated to obtain optimal single-wheel turbine performance. The blade length is 12 cm, 80 rpm, 25.45 Watt power and 42.45% efficiency [8]. Asrofull, in his research on kinetic turbines with variations in the input angle with the type of bowl blade. The optimum value for the input of the bowl blade type is 10o, 100 rpm rotation, 19 Watt power and 38% efficiency [9]. Kaprawi conducted research on vertical shaft kinetic turbines regarding the effect of turbine blade geometry in order to obtain the best turbine blade performance. Optimum blade thickness at 12% to 18% of the thickness that is often used. The thickness of the blade is very influential on whether or not the blade is strong against resistance/drag. [10]. Now has developed research on kinetic turbines using a blade is not fixed or hinged blades. Some that have been researched, among others, by Bo Yang, conducted research on the performance of a vertical axis hinged blade kinetic turbine called the Hunter turbine [11]. Experiments were carried out with flow visualization on a small model to provide some basic motion of each blade in each drum position. A 2-dimensional CFD simulation is then used to obtain detailed information about the flow field, including pressure and velocity contours, as well as pressure distribution on the blade surface. The blades used are made of steel plates with a semicircular shape mounted on the shaft using hinges [12].

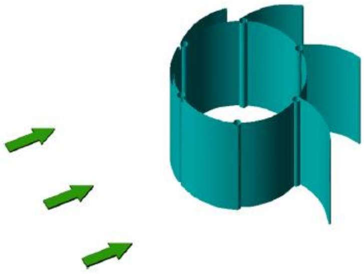

Figure 1. Hunter Turbine (Inner hinged turbine)

Yesung Allo, analyzed a zero head cross flow turbine, with the number of blades as independent variables: 12, 6, 4 blades, also variations in blade motion, namely, fixed blades and hinged blades. Optimal results were obtained at fixed blade motion, 12 blades, 89.9 rpm, 29.2 Watt power and 0.47% efficiency [13]. Currently, research on kinetic turbines is still lacking, especially kinetic turbines with vertical shafts, it is necessary to develop this type of turbine because the water potentials in rural areas are very large to be managed. The purpose of research on kinetic turbines is to produce optimal performance, in this case determining the right number of blades. The research that will be carried out this time is to examine the performance of the turbine, by using a hinged blade mounted on the outside of the disc diameter. The hope of using this turbine is an increase in turbine performance compared to using a kinetic turbine with a fixed blade.

II. METHOD

The research methodology for this research is the actual experiment. This study uses research equipment designed according to the size of the external hinged blade kinetic turbine to be studied. The research methodology is carried out, which will analyze the effect of increasing the number of blades on a kinetic turbine, namely, a hinged turbine using a hinge on the outside of the runner. Turbine performance will be obtained, namely the power and efficiency of an externally hinged kinetic turbine from the variation of the specified number of blades. The location of the research was carried out in the Mechanical Engineering laboratory / workshop, more precisely in the Mechanical Engineering laboratory of the Manado State Polytechnic and will be applied to irrigation canals at 4 sluice gates in Talawaan Utara Minahasa village. The application of appropriate technology with the application of science is carried out in this research. The solution to the energy crisis, which is still a polemic, must be found. One way is to take advantage of the potential of natural resources that are around. The resource/potential that has not been developed much is water resources, either rivers or irrigation canals. Currently, direct research is applied by utilizing the speed of water flow in irrigation canals to become an important object.

The moving fluid flow / flow velocity is considered as energy where the fluid flow has a very large velocity energy. The advantages of the water turbine under study are that the kinetic turbine utilizes flow velocity only, does not require a head and is portable.

The shape of the kinetic turbine blade used is a curved blade, with variations in the number of blades being 6,8,10,12 blades. The performance of a kinetic turbine is determined by the efficiency and power of the turbine.

The parameters of the efficiency and power of the kinetic turbine depend on: flow rate, water flow velocity, the size of the kinetic turbine blades, and the number of kinetic turbine blades. The current research is taking the independent variables, namely variations in the number of blades: 6, 8, 10, 12, as well as the dependent variable, namely the efficiency and power of the kinetic turbine. The kinetic turbine device used during the study was a turbine runner which consisted of 3 main parts, namely a shaft with a diameter of 32 mm, stainless steel material, a disc with a diameter of 40 cm, and a blade totaling 6, 8, 10, 12 blades with a thickness of blades. 1 mm of stainless steel mounted on the circumference of the disc, as shown in Figure 2.

Figure 2. Runner Turbine

The tachometer serves to measure the turbine rotation, as shown in Figure 3.

Figure 3. Tachometer

The spring balance functions to measure the load/force at each turbine rotation variation, as shown in Figure 4.

Figure 4. Spring Balance

Irrigation channel at floodgate 4 Talawaan Village, North Minahasa Regency, as shown in figure 5.

Figure 5. Turbine placed in a water line

III. RESULTS AND DISCUSSION

Table 1. Relationship of rotation n (Rpm) and turbine power

Speed (rpm)	Turbine power (watts)
239	0
213,9	20,53
213	43,10
191,1	59

Turbine power is highly dependent on the amount of rotational speed (rpm). The smaller the turbine rotation (rpm) due to loading, the greater the power generated.

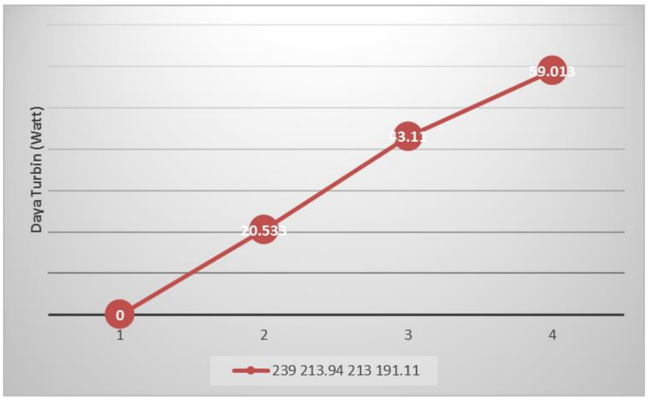

Figure 6. Graph of turbine rotation and power relationship

Table 2. Relationship of rotation n (Rpm) and turbine efficiency

Speed (rpm)	Efficiency (%)
239	0
213,9	5,152
213	10,815
191,1	14,806

Turbine efficiency is highly dependent on the amount of rotational speed (rpm). The smaller the turbine rotation (rpm) due to loading, the greater the efficiency of the turbine will be.

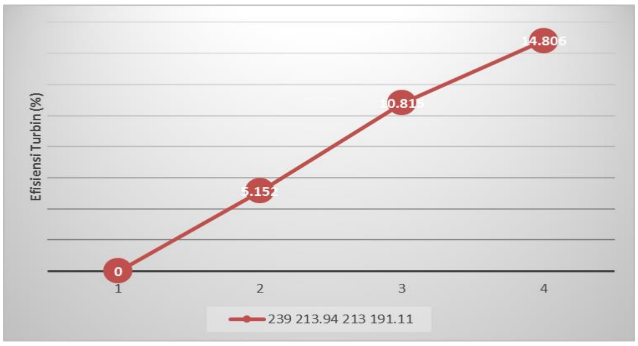

Figure 7. Graph of the relationship between turbine rotation and efficiency

TABLE 3. The relationship between the number of blades and turbine power

Number of blades	Daya turbin (watt)
6	25,81
8	41,96
10	59,01
12	44,12

As the number of blades increases, the turbine power will increase. But in this study, the optimal number of blades is 10 blades. This is caused by the limited movement of the hinged blades, due to the increasingly tight distance between the blades so that the water flow cannot hit the blades optimally resulting in a decrease in turbine rotation.

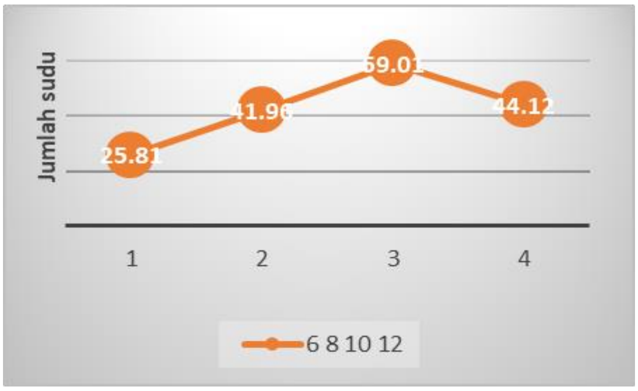

Figure 8. Graph of the relationship between the number of blades and turbine power

IV. CONCLUSION

1. The optimal number of vertical shaft kinetic turbine blades with external hinged blades is 10 blades, 191.11 rpm rotation with turbine efficiency of 14.806% and turbine power of 59.01 Watts.
2. The given load will affect the turbine rotation, the turbine rotation affects the power generated, the smaller the turbine rotation, the greater the turbine power generated. The external hinged blade kinetic turbine has an optimal value of 10 blades.

DECLARATION

Funding	Manado State Polytechnic Institution Funding, through the Center for Research and Community Service (P3M).
Conflicts of Interest/ Competing Interests	Not conflicts of interest to the best of our knowledge.
Ethics Approval	Yes, in conducting the research, the researchers collaborated with the Talawaan Village Government for the use of irrigation canals, where the turbines will be placed.
Consent to Participate	The Talawaan Village Government participated in this research, with a Statement of Willingness to Collaborate.
Consent for Publication	One of the mandatory output forms of research that is carried out is by sending articles to International Journals until they are published.
Availability of Data and Material	The research carried out is supported by research funds; the need for turbine manufacture can be met, as well as the availability of measuring instruments to support research, so that data collection can be carried out.
Authors Contributions	The task of the team leader is to lead the team in every activity from the design/build of the outer hinged blade kinetic turbine, experimental data collection, data analysis, evaluation, research seminars, preparation of: - research reports, articles - indexed international journals, - Simple patent. Assisting the task of the team leader in the activities of the design/build of the outer hinged blade kinetic turbine and analyzing the resulting electrical output (trial).
Code Availability	Not applicable.

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AUTHORS PROFILE

Silvy Dollorossa Boedi, was born in Surabaya, Indonesia, on 2nd of February 1975. She obtained her Bachelor degree in Mechanical Engineering from the University of Sam Ratulangi, Manado, Indonesia and Master degree in Mechanical Engineering from the University of Brawijaya, Malang, Indonesia. She is currently a Ph.D. student under supervision of Prof. Rudy Soenoko. Her research about A Vertical Axis Hinged Blade Kinetik Turbine Performance. In 2008 she received an offer to join the Mechanical Engineering Department, The Manado State Polytechnic, Manado, Indonesiaas lecturer.

Josephine Sundah, is a lecturer at the Department of Electrical Engineering, Manado State Polytechnic. Taking Masters education at Brawijaya University, Malang. As a lecturer who is active in carrying out the Tri Dharma of Higher Education and currently serves as the head of the Digital Electronics and Power Electronics laboratory in the Electrical Engineering Study Program.

Meidy Kawulur, is a lectuter at the Department of Mechanical Enginering, Manado State Polytecchnic. Taking Master's Degree at Brawijaya University Malang at the Mathematics and Natural Sciences Faculty. Currently as a lecturer who is active in research and community service. His current position is secretary of the Center for Excellence in Polimdo Technology unit.

Franklin Bawano, graduated S1 in Mechanical Engineering Department, Bandung Institute of Technology in 2002, graduated S2 in Master of Engineering Program at the Faculty of Engineering, Department of Mechanical Energy Conversion at Hasanuddin University, Makassar in 2010. Currently, he is a permanent lecturer at the D – IV Study Program of Mechanical Production and Maintenance Engineering at the Polytechnic Manado State.