VOL. 13, NO. 1, JANUARY 2018 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

DEVELOPMENT OF CROSS FLOW TURBINE WITH MULTI NOZZLE

Corvis L. Ranterung[1], Titus Tandiseno[2] and Mika Mallisa[3]
[1]Department of Mechanical Engineering, Paulus Christian University of Indonesia, Makassar, South Sulawesi
[2]Department of Electrical Engineering, Paulus Christian University of Indonesia, Makassar, South Sulawesi
[3]Department of Accounting, Paulus Christian University of Indonesia, Makassar, South Sulawesi
E-Mail: corvisrante@yahoo.com

ABSTRACT

Current cross flow turbines are simple, inexpensive construction and appropriate technology as a rural micro hydro power plant where potentially abundant water potential is available. But the lack of cross flow turbines is of lower efficiency compared to other impulse turbines because it uses only one nozzle. The objective of the research is to improve the performance of multi nozzle cross flow turbine. The research method is to test the characteristic performance of turbine cross flow with multi nozzle through measuring, collecting and analyzing data with the relevant formula. The result of this research is the improvement of performance of multi nozzle cross flow turbine development which reach 83,60% efficiency.

Keywords: cross flow turbine, multi nozzle.

1. INTRODUCTION

Population growth, technological and industrial development of a country will increase energy consumption, so it must strive to increase energy supply [1]. The development and economic development to achieve a decent standard of living will increase the demand for energy in the future. This condition can turn energy into a very promising commodity profit opportunity. These opportunities encourage various parties to conduct efforts to provide and manage energy efficient by utilizing new and renewable energy sources such as water energy. Water energy is a renewable energy that can be derived from nature directly [2]. Indonesia has enormous water energy resources, can be used as a source of electrical energy. The provision of sufficient, easy, inexpensive, environmentally friendly and sustainable electricity is indispensable for the future development of the Indonesian economy [3].

The availability of potential macro and micro-scale water is very abundant in rural areas can be used as a driver of cross-flow turbines to support government programs that promote the utilization of electrical energy sources from water energy. Electrical energy has become a staple in human life. The utilization of water resources in each location is expected to overcome the problem of power shortage in the area [4]. At present only 53% of the total population of Indonesia has access to power grids and still there are 47% in remote areas not yet covered by the power grid due to limited infrastructure and generating capacity. Water power is already being used around the world as a natural source as a very important power plant. Small-scale renewable energy whose cost is most effective to supply electricity to remote villages far from the country's electricity transmission lines. Electrical energy is the most widely used in supporting human life, wherever we live, electricity has become a primary need for every circle, in urban and rural areas the need for electricity continues to increase [5].

Utilization of the potential of water energy as a micro-hydro power plant as a reliable energy source. The main component of a micro hydro power system is a water turbine to convert potential energy of water into mechanical energy. The magnitude of the potential energy of water required for micro hydro power generation is calculated based on the function of head and flow rate [6]. Then during this much used water energy is the potential of large water that has a having height of head and large flow rate.

The development of micro hydro power plants can provide additional electricity supply for the community. Micro-hydro plants are well suited to supply electricity in rural areas, which is usually difficult to reach by state power grids. Utilization of hydro power as a turbine driver will motivate the government and society for the environment must be sustainable so that the water flow is continuous and maintained. The potential energy and kinetic energy of the water are converted to mechanical energy in the turbine and then used to drive the electric generator [7].

There are many types of water turbines that are used as hydroelectric power plants, but the best selection of turbines must be tailored to the location characteristics of head and flow of available water. Selection of turbines depends on the desired power and speed as needed. Cross flow turbines are the best type for hilly areas with low discharge rates and moderate heads. Cross flow turbine performance is strongly influenced by turbine structure configuration and flow characteristic on turbine blades, nozzle shape, blade angle and number of turbine blades. The angle that surrounds the runner serves as a capture of the kinetic energy of the water that strikes the surface of the blade causing the runner to transmit the kinetic energy of the water into mechanical energy on the turbine rotor [8].

Cross flow turbine is very suitable for use as a powerhouse in free flow water, small flow rate with low head. Phenomenon of rotation and work efficiency of cross flow turbine is also strongly influenced by the angle of the rotor blade. Then the general parameters affecting turbine efficiency are the form of turbine blades and the velocity of water flow. Based on the study of theories found the main and urgent problem, that there are still many turbine blades that potentially generate mechanical energy, but do not get the water jets from the nozzle. The turbine produces a high vibration because the turbine blade spin is unbalanced, the high shaft vibration causes the turbine shaft to decrease and the shaft bearing is quickly damaged [9]. This causes turbine power to drive low and unstable power generators causing not optimal performance, turbine lifetime and generators

The purpose of this research is to improve the performance of multi-nossel cross-flow turbine development including rotation, torque, power and turbine efficiency. The development of renewable energy science and technology, especially micro hydro, has a mechanical component in the form of a water turbine as a microhydro power plant. The test model is carried out on a laboratory scale to obtain cross flow turbine characteristics. Data collection and analysis using existing formulas to obtain power generation and turbine efficiency.

2. LITERATURE REVIEW

Cross flow turbines are impulse turbine water turbines which are more advantageous use than using water wheels, or other types of micro hydro turbines. The use of this turbine for the same power on a water wheel is cheaper, since the cross flow turbine size is smaller and more compact [10]. The high effectiveness and efficiency of cross flow turbine is caused by the use of water energy in the turbine is done twice, the first energy collision water on the blades when the water starts to enter the blade, and the second is the propulsion of water on the blades when the water will leaving the runner. The existence of turbine water works on turbines provides high effectiveness in cross flow turbines [11].

The principle of cross-flow turbine work was first discovered by A.G.M. Michell in 1903, later developed and patented by Donat Banki so named Turbin Banki [12]. The cross flow turbine consists of two main parts namely the nozzle and the turbine runner. The turbine runner is constructed of two discs or parallel diks connected together with several curved spindles arranged in series. The nozzle serves to emit a pressurized water flow, converting the water pressure energy into water kinetic energy and directing the water jet to the turbine blades. The water jets from the nozzle pound the front turbine blades and then the cross flow of water jets again enter the runner's inner blades and the water out on the outside of the blade [13].

This research is very strategic and urgens to conduct a deeper study on the performance of turbine cross flow multi nossel. This cross flow turbine is essential for improved performance, because of all types of water turbines, the most widely used cross flow turbine and suitable as a micro hydro power plant in the countryside. This turbine manufacturing process is quite easy, has a simple construction, operation and maintenance, is relatively inexpensive and able to operate with high efficiency and effectiveness, because once a water jet from the nozzle twice moves the turbine blades [14]. Optimizing the performance of cross flow turbines that use water energy as a source of power generation is to support national energy independence and reduction of dependence on fossil fuels as an effort to create clean development and blue sky program.

Cross flow turbine is a tool to convert water energy into mechanical energy in the form of motion on the turbine shaft. The water flow is directed into the turbine rotor through the inlet nozzle (jet) then water flows through the first rotor in the turbine blade and then exits through the turbine exit. The power generated through the power output shaft of the turbine can be used to drive the electric generator, compressor, water pump and others. The research concentrates on the main part of the cross flow turbine, especially the radial runner and the shape of the water transmitter nozzle. There is also developed software for designing a latitude turbine, where several parameters have to be entered and there are still some calculations to be done where the results should be entered [15].

Impulse turbines, which have the simplest design and are often used for small hydro head systems. The lower the head and the amount of water needed for a given amount of power, the smaller required equipment at lower cost [7]. The pipe carries water to the nozzle, where the kinetic energy of the water is used to push or push the turbine blades and shafts connected with the generator or other equipment. In general, hydro energy can be predicted, start time and small output time can be easily adjusted, more haandal, low operational costs, durable technology and no impact on the environment. The utilization of cross flow turbine for the potential of available water energy in the surrounding area is very suitable considering the cross flow type impulse turbine has the appropriate characteristics used in water sources with high fall and small flow rate. Variables that greatly affect turbine performance are the number of blades associated with the number of turns, turbine power, and turbine efficiency. The available water power is highly dependent on the level of the head and the flow discharge can not be enlarged with the addition of the turbine.

The research was conducted by taking some of the inputs used are the flow rate, the falling height, the slope and the width of the cross section, the outer diameter of the turbine and the width of the turbine. Meanwhile, the quantity created as a variable is the number of nozzles in the multi-nosse cross flow turbine [9, 16]. The equations used to calculate the performance of the multi-flow cross-nozzle turbine are as follows:

Head

$$h = \frac{P}{\rho . g} \text{ (m)} \quad (1)$$

Flow rate:

$$Q = \frac{V}{t} \text{ (m}^3\text{/s)} \quad (2)$$

Water power

Water power is the result of multiplication of gravity acceleration, water density, water discharge and high water fall or head are as follows:

$$P_{water} = 9,81.h.Q.g.\rho \text{ (Watt)} \quad (3)$$

Turbine power

Turbine power is a water energy that is converted into mechanical energy on its axis, which is then converted into electrical energy.

$P_{turbine}$ = (Torque x Speed of the turbine shaft)
$= (\tau \times \omega) = (F.r) \times (2\pi.n)$ (4)

Turbine efficiency

Turbine efficiency is the ratio of output power and input power. Efficiency is a measure of how much energy is actually converted. Where the output power is the power generated by the turbine and the input power is the available water power [8, 17]. Some energy will be used to overcome the friction force in every energy conversion process

$$\eta_{Turbine} = \frac{Power_{output}}{Power_{input}} = \frac{P_{Turbine}}{P_{Water}} \quad (5)$$

3. MATERIAL AND METHODS

Materials and tools of research are cable, rivet, pulley, belt, shaft, welding electrode, sandpaper, paint, frame, iron, saw, welding machine, drill machine, meter, Stop Watch, Torsimeter, Flowmeter, Multimeter, Dial gauge, Manometer, Thermometer, Micrometer, Electrical regulator, Voltmeter, Amperemeter, Thermometer, Measure Glass. The procedure of the implementation of this research activity is the preparation of materials and Instruments, installation. Calibration, measuring cross flow turbine performance variables, analyzing, evaluating turbine performance scheme installation of turbine cross flow research multi nozzle.

Figure 1. Runner Cross Flow Turbine

Figure 2. Multi Nozzle and Manometer

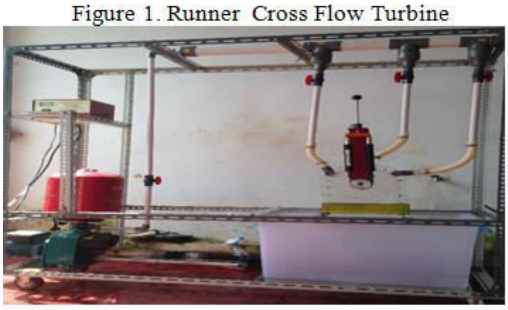

Figure 4. Instalasi Experiment

Figure 5. Research Activities

The instrument used in the research is

a) Manometer is measure the amount of water pressure in pipeline, with known water pressure hence falling height, flow discharge can be calculated. Head is water pressure, elevation difference or water fall height in calculating water power as turbine drive.

b) Meter is used to measure the height of water fall, reservoir dimension and water pipe length

c) Measuring cup to measure water discharge. The measurement of the amount of water flow is measured in liters per second or cubic meter/ sec). To measure the flow rate of the volume of water of unity of seconds, measured by glass measuring method or fill

VOL. 13, NO. 1, JANUARY 2018 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

the container by dividing the volume of the container by the time of filling.

d) Balance of spring to measure load and torque on turbine

e) Tachometer to measure the rotation of the turbine shaft powered by water

f) The thermometer is to measure turbine inlet water temperature

4. RESULT AND DISCUSSIONS

Based on research result of development of turbine cross flow multi nozzle is angle of nozzle and blade turbine is 30^o, number of nozzle 3 pieces with amount of 24 blades and data analysis obtained that higher water flow rate, hence will produce bigger water power and impact on increasing runner rotation. Turbine research results on the performance of cross flow turbine multi nozzle with water flow rate variation can be illustrated in Figure 6 graph relation of turbine power to variation of water flow rate change as follows:

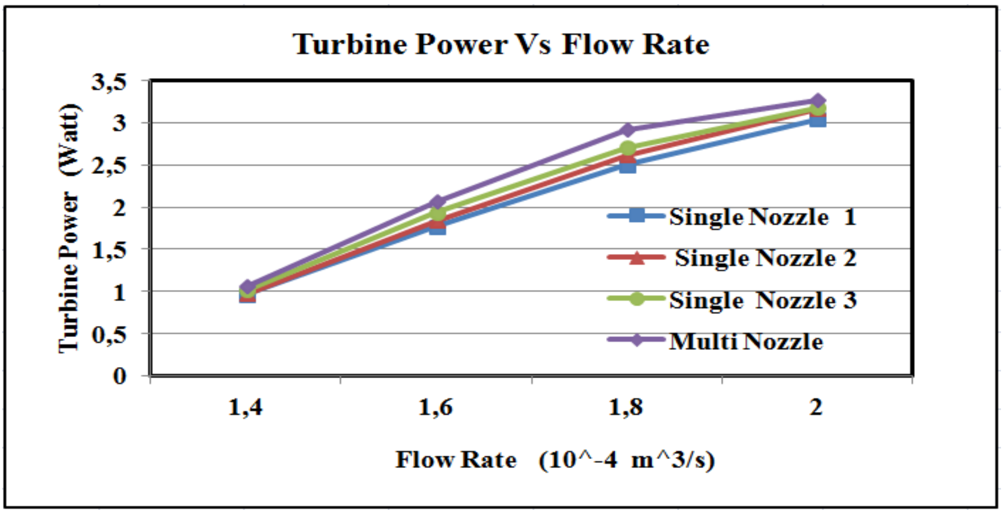

Figure-6. Turbine power graphs of water flow rate.

In accordance with Figure-6 on the graph of the relationship of water power to the flow of water illustrates that the greater the flow of water flowing into the turbine is the greater the turbine output power but when it reaches its optimum working point with high speed, the resulting power will decrease. This is caused by the maximum discharge, the flow rate is very high, it will happen high flow turbulence and there is loss of energy in the water flow in the plumbing [6]. The study was conducted by variation of the number of nozzle, the variation of water discharge and its effect on water power is possible because the water flow rate changed.

Based of the results of the research it was found that the power of single nossel turbine output at the lowest discharge of 1.48 x 10-4 m3 / s produces 1.01 Watt power at 156 rpm rotation while multi nozzle cross flow turbine obtained higher power 1.05 Watt nozzle with speed 161 rpm. Then at a maximum water flow of 2.0 x 10-4 m3 / s for turbine flow flow with a single nozzle only produce 3.17 Watt turbine power, maximum rotation of 490 rpm and for multi flow turbine nozzle turbine obtained that turbine output power increased reached 3.26 Watt with optimal rotation of 503 rpm. As a result of the increase in water discharge the momentum and torque will increase given at this second level will also increase, resulting in an increase in turbine power, the greater the water discharge given will increase the turbine spin, the higher the loading should be given, its efficiency will increase [12].

ARPN Journal of Engineering and Applied Sciences

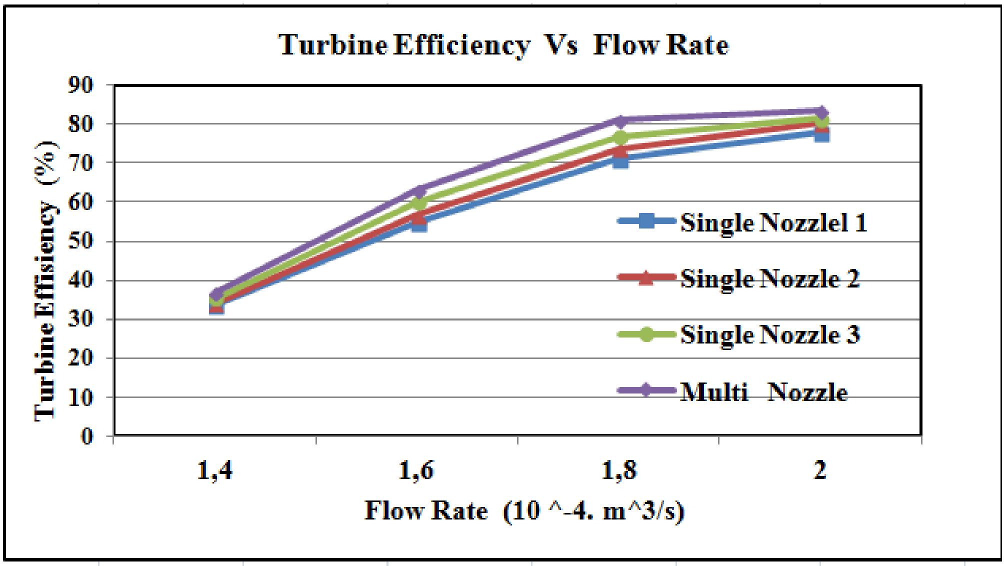

Figure-7. Turbine power graphs of water flow rate.

Based on the analysis of Figure-7 on the graph of turbine efficiency relationship and water debit on the multi nozzle cross flow turbine test, it is shown that the turbine efficiency improvement is directly proportional to the increase of water discharge in turbine blades. Multi nozzle of cross flow turbines emit water in turbine blades with maximum water flow efficiency improved compared to a single nozzle. This is due to the water velocity energy entering the runner blades more evenly and mashing more precisely the front of the blade resulting in increased torque and turbine spins [7]. Therefore, the multi nozzle turbine produces a more stable torque and the efficiency of the cross flow turbine increases, this stability of the spin is required for better turbine rotation quality. Multi nozzle cross flow turbines provides the highest efficiency due to the more efficient use of water energy in turbines compared to single-pass cross-flow turbines. This is due to the energy of the water velocity entering the runner blade is more utilized [8]. While the higher the speed of the turbine runner then the output power and turbine efficiency will be greater but when it reaches its optimum working point with high speed, the power generated will decrease. This is because when turbine rotation is very high, the momentum transfer between water and turbine is so small that the resulting force will be small [9].

The efficiency of the multi flow nossel cross flow turbine has increased to 83, 60%, while the efficiency of the single nozzle cross flow turbine is lower at only 81, 37%. Through this research, it is found that multi-nossel cross flow turbine influences cross flow turbine performance improvement in the form of rotation, torque, power and Efficiency. It was also found in this study that multi nozzle cross flow turbines affect cross flow turbine performance improvements in the form of rotation, torque, power and efficiency. The performance of this multi nossle cross flow turbine derives maximum output power and turbine efficiency [10]. The emission of water coming out of the transmit nozzle pounds and drives the turbine so that the turbine spins and the increase in efficiency is also proportional to the increase in water flow rate variation [11]. The greater the water discharge provided will increase the turbines rotation and the higher the loading must be given so that its efficiency is also improved, resulting in the highest efficiency of multi nozzle cross flow turbine

5.CONCLUSIONS

The higher the water flow rate, the greater the power and efficiency of the turbine and the performance of the multi nozzle cross flow turbine is higher than a single nozzle turbine. The performance of a single nozzle cross flow turbine is only 3.17 Watt with an efficiency of 81.37%; while multi nossel cross flow turbines are increased which reaches turbine power is 3,264 Watt with efficiency 83, 60%.

ACKNOWLEDGEMENTS

The authors wish to thank the Directorate of Research and Community Service, Directorate General of Higher Education, Ministry of Research, Technology and Higher Education Indonesia for its support.

REFERENCES

[1] Haurissa. J., Soenoko. R, Wahyudi S., Irawan Y. S. 2012. The Cross Flow Turbine Behavior towards the Turbine Rotation Quality, Efficiency, and Generated Power. Journal of Applied Sciences Research. 8(1): 448-453.

[2] Rantererung. L.C., Soeparman. S., Soenoko. R., Wahyud. S. 2016. Dual Nozzle Cross Flow Turbine as

an Electrical Power Generation. ARPN Journal of Engineering and Applied. 11(1): 15-19.

[3] Rantererung. L.C., Soeparman. S., Soenoko. R., Wahyud. S. 2016. The Dual Nozzle Cross Flow Turbine Performance. ARPN Journal of Engineering and Applied. 11(13): 8538-8543.

[4] Kokubu K., Toshiaki, Sung. W.S., Choi. D.Y. 2012. Performance Improvement of a Micro Eco Cross-Flow Hydro Turbine. Journal of the Korean Society of Marine Engineering. 36(7): 902-909

[5] Gudukeya. L., Madanhire. I. 2013. Intern Efficiency Impovement of Pelton Wheel and Cross Flow Turbines in Micro-Hydro Power Plants: Case Study. International Journal of Engineering and Computer Science. 2(2): 416-432.

[6] Sinagraa. M., Sammartanoa. V., Aricòa. C., Collurab. A., Tucciarellia. T. 2014. Cross Flow Turbine Design for Variable Operating Conditions12th International Conference on Computing and Control for the Water Industry, CCWI2013. Elsevier. Procedia Engineering. 1539-1548.

[7] Khan. A.M., Badshah. S. 2014. Design and Analysis of Cross Flow Turbine for Micro Hydro Power Application using Sewerage Water Research Journal of Applied Sciences, Engineering and Technology. 8(7): 821-828.

[8] Patel. U.S., Pakale. N.P. 2015. Study On Power Generator By Using Cross Flow Water Turbine In Micro Hydro Power Plant. International Journal of Research in Engineering and Technology. 4(5): 1-4.

[9] Chen Z.M. and Choi, Y.D. 2013. Performance and Internal Flow Characteristics of a Cross-Flow Turbine by Guide Vane Angle. IOP Conference Series: Materials Science and Engineering. 52: 1-6.

[10] Legonda. A.I. 2016. An Investigation on the Flow Characteristics in the Cross-Flow Turbine-T15 300. Journal of Power and Energy Engineering. 4: 52-60.

[11] Sammartanoa V., Morrealea. G., Sinagraa M., Collurab A. and Tucciarelli T. 2014. Experimental Study of Cross-Flow Micro-Turbines for Aqueduct Energy Recovery. Procedia Engineering of the 16th Water Distribution System Analysis Conference. 89: 540-547.

[12] Nasir B.A. 2013. Design of High Efficiency Cross-Flow Turbine for Hydro-Power Plant International Journal of Engineering and Advanced Technology. 2: 308-311.

[13] Rifat A. and Mahzuba I. 2014. A Case Study and Model of Micro Hydro Power Plant Using the Kinetic Energy of Flowing Water of Surma and Meghna Rivers of Bangladesh‖ The International Journal Of Science & Technology. 2(1): 87-95.

[14] Bilal A. N. 2013. Design of Micro Hydro Electric Power Station‖ International Journal of Engineering and Advanced Technology. 2(5): 39-47.

[15] Paish. O. 2001. Micro-hydropower: status and prospects Special Issue Paper Proc Instn Mech Engrs Vol 216 Part A: J Power and Energy: 31-40.

[16] Marco. C. 2015. Harvesting Energy from In-Pipe Hhydro Systems at Urban and Building Scale International Journal of Smart Grid and Clean Energy 4(4): 316-327.

[17] Archana T., Pandey S.K and. Dubey S.C. 2015. Hydro Power Opportunity in the Sewage Waste Water‖. American International Journal of Research in Science, Technology, Engineering & Mathematics. 10(2): 179-183.